Strategic Plan for ITS Communications

Prepared for:

Arizona Department of Transportation

in cooperation with
U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

This report presents the results of a study by Kimley-Horn and Associates, Inc. for Arizona Transportation Research Center to develop strategies for the State of Arizona to evolve/develop state-of-the-art communication infrastructure(s) to support Intelligent Transportation System(ITS) deployments to improve the overall level of safety and efficiency of Arizona's highway network.

The report reviews the ITS National Plan (3/95) and Arizona's ITS priorities as defined by the study Technical Advisory Committee. The report reviews existing and planned ITS-related systems within Arizona. The Freeway Management System(FMS) in the Phoenix area is a state -of-the-art system that includes video surveillance, incident detection, ramp metering, and many other functions. Future major systems being considered include an FMS in Tucson and a rural FMS in Flagstaff for the I-40 corridor.

The report recommends an evolution to open standards based communication infrastructure. The report discusses wireline modem technologies, the U.S. digital hierarchy, SONET fiber hierarchy, and multiplexing and EIA-232. A discussion of system level digital communication system design is presented and includes information on ITS data sources.

The report concludes with recommendations for statewide, metropolitan area, and rural area communication infrastructure(s) plus other considerations. The report concludes that open standards facilitate modular, expandable, and scaleable communication infrastructures to accommodate the evolutionary nature of ITS service definition(s), benefit validation(s), and deployment(s).

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

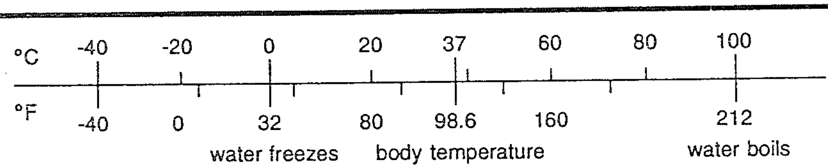
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
ml	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
ft oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

TEMPERATURE (exact)

Symbol	When You Know	Do The Following	To Find	Symbol
°F	Fahrenheit temperature	°F - 32 ÷ 1.8	Celcius temperature	°C



APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.19	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.31	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T

TEMPERATURE (exact)

Symbol	When You Know	Do The Following	To Find	Symbol
°C	Celcius temperature	°C x 1.8 + 32	Fahrenheit temperature	°F

METER: a little longer than a yard (about 1.1 yards)
LITER: a little larger than a quart (about 1.06 quarts)
GRAM: a little more than the weight of a paper clip
MILLIMETER: diameter of a paper clip wire
KILOMETER: somewhat further than 1/2 mile (about 0.6 mile)

*SI is the symbol for the International System of Measurement

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EXECUTIVE SUMMARY

Arizona has established as a goal the deployment of Intelligent Transportation Systems (ITS) that will improve the safety and efficiency of the State's transportation infrastructure.

In "Assessment of ITS Benefits, Early Results" (dated August 1995 by Mitre under contract to FHWA), the benefits of ongoing early ITS-related programs were discussed as related to the goals stated in the National ITS Program Plan. Examples of the benefits identified include the Minnesota Department of Transportation's (MNDOT) freeway ramp meter system which increased capacity (from 1800 to 2200 vehicles per lane per hour), increased average speed (from 34 to 46 MPH), and reduced accident rates 27%. Another example is a London video surveillance system with speed enforcement cameras that have reduced speeds by approximately 10%, accidents by more than 20%, and serious injuries and fatalities by about 50%. Another example is an Oregon Commercial Vehicle Operation (CVO) electronic clearance program which enabled an increase of 90% in weighings and 428% in safety inspections between 1980 and 1989 with a staff increase of only 23%. Benefits are also projected for ITS programs that have not yet reached the data collection and evaluation phases. Although many existing programs provide many positive verifications, the exact nature and extent of ITS benefits are still being defined and evaluated in current and planned ITS projects.

The National ITS Program Plan identifies 7 user service bundles and 29 subordinate user services. Many ITS-related systems have been deployed. Future ITS deployments and operations will integrate these existing systems through federal, state, and local partnerships that will include public and private participation. The 5-year ITS deployment vision is an era of travel information and fleet management.

Arizona's ITS priorities have been identified as: 1) Metropolitan Advanced Travelers Management System (ATMS), 2) Rural Emergency Management, 3) Rural and Metropolitan Advanced Traveler Information System (ATIS), 4) CVO including North American Free Trade Agreement (NAFTA) border crossings, 5) integration of Freeway Management System (FMS), metropolitan FMS, and signal systems, and 6) integrated multiple Traffic Operations Center (TOC) requirements.

A modern communication infrastructure is required to support emerging and evolving ITS services. Existing ITS-related systems in Arizona include: 1) Phoenix Arizona Department of Transportation (ADOT) FMS, 2) many jurisdictional and some state-owned signal systems, 3) Weigh-in-Motion/Automatic Vehicle Count (WIM/AVC) stations along interstates, 4) ATR for recording traffic counts, 5) call boxes, and 6)

SCAN® automated weather stations. Future ITS plans include Freeway Management System's for Tucson and Flagstaff and integration of Maricopa County FMS with jurisdictional signal systems for regional ATMS/ATIS capabilities.

ADOT has limited existing communication facilities. ADOT has a state-wide Wide Area Network (WAN) interconnecting Local Area Networks (LANs) via 1.544 Mbps, DS-1 circuits. Reports indicate that this network is heavily loaded. ADOT has radio and microwave systems used for construction and maintenance. Based on recent Federal Communications Commission (FCC) rule changes, new vendor equipment, for certain Part 90 bands, must support more spectrally efficient modulation/channelization capabilities. This offers Arizona an excellent opportunity to obtain wireless communication capacity, essentially on normal upgrade schedules, provided a plan is in place.

The Phoenix FMS has an existing communication infrastructure; however, it uses a six year old architecture based on non-standard proprietary Frequency Division Multiplexing (FDM) techniques. A plan should be developed to accommodate upgrades to integrated ITS requirements. Fortunately, the expensive fiber cable plant should be usable and should accommodate more modern standards-based fiber terminals.

The recommended strategy for evolving to a standards-based communication architecture is based on the widely deployed T1 digital hierarchy and recently emerged Synchronous Optical Network (SONET) multiplexing standards. These standards, along with subrate multiplexing for lower speed EIA-232 or equivalent data rates, provides a modular, scalable, and expandable suite of data rates that is well supported by cost-effective products for private network implementation as well as compatible interfaces into commercial services. In addition, wire, wireless, and fiber media options may be employed, as advantageous, for most links. It should be noted that Single Mode Fiber Optics (SMFO) cable has reached cost parity with wire and offers significant advantages in terms of media bandwidth and repeaterless distances. Fiber terminals continue to be more expensive, but the cost difference is narrowing. Compatible wireless microwave equipment costs are also on a downward trend and are often cost competitive with wire and fiber depending on application and installation requirements.

It is recommended that ADOT develop a statewide communications infrastructure using fiber and appropriate SONET (OC-n) standard circuits. We strongly endorse the state's program for creating a private/public partnership to install a fiber infrastructure along the interstates and offer suggested technical goals to achieve in partnership negotiations. This private network should accommodate private long distance access to local telephone exchanges and provide cost-effective statewide access for voice, sensor, variable message sign (VMS), etc.

It is recommended that ADOT adopt the National Electrical Manufacturers Association (NEMA) National Transportation Control/ITS Communication Protocol (NTCIP) standard for controller communication links and an outreach/support program to help various state agencies and local jurisdictions understand and implement these links in a complementary manner.

1.0 INTRODUCTION

The state of Arizona has established the goal of deploying state-of-the-art systems that will improve the overall safety and efficiency of the state's transportation network. These goals are in concert with both state requirements and the national Intelligent Transportation System (ITS) program.

The national ITS program identifies a suite of recommended ITS services. State and local jurisdictions can select which ones to implement in support of local requirements. The national definition of these services will provide consistency so that data collected and/or distributed within a particular ITS service can be shared with other local, state, and national ITS agencies or services.

A transportation system must be distributed to support the geographical areas that require these services. ITS systems will have sensors, terminals, kiosks, variable message signs, controllers, Traffic Operations Centers (TOC), and many other devices distributed over the geographic area where transportation services are provided. To support the deployment of these services, a modern, cost-effective, communications infrastructure is required to collect, integrate, process, and distribute this ITS data.

It is the purpose of this report to identify communication technologies that are suitable for supporting the deployment of ITS services within Arizona and the key elements required in a strategic ITS Communication plan for the Arizona Department of Transportation (ADOT). This report is organized as follows:

1.0 INTRODUCTION
2.0 ITS SERVICES
3.0 EXISTING ADOT ITS-RELATED SERVICES
4.0 PLANNED ITS SERVICES
5.0 EXISTING COMMUNICATION INFRASTRUCTURE
6.0 RECOMMENDED ITS COMMUNICATION STRATEGY
7.0 CONCLUSIONS AND RECOMMENDATIONS

2.0 ITS SERVICES

Evolution to a strategic ITS communications plan should consider:

- The National ITS Program Plan.
- Arizona ITS Requirements.

2.1 *THE NATIONAL ITS PROGRAM PLAN*

The National ITS Program Plan, First Edition, March 1995 consists of four (4) documents:

- An Executive Summary.
- A Synopsis.
- Volume I, Goals of ITS.
- Volume II, User Services.

ITS deployments and operations will unfold through federal, state, and local partnerships that will encourage private company participation to develop and market ITS products and services. The National Plan develops the framework to support this evolution. As such, the National Plan will:

- Promote shared ITS goals.
- Guide ITS investment decisions.
- Encourage coordination.
- Maintain a forum on deployment.
- Ensure ITS is Intermodal.

The National Plan currently identifies 7 User Service Bundles and 29 subordinate User Services that are presented in **Table 2.1-1**. Many systems have already been deployed (**Table 2.1-2** from National Plan) which include ITS functionalities that will be integrated, perhaps after upgrading, into future ITS deployments. The plan is actually a multiphased process that builds upon itself. It is based on participation and input from federal, state, and local government stakeholders, plus private stakeholders. It is based on currently defined requirements and visions; however, as it evolves and more experiences are acquired, the National Plan will be modified accordingly and subsequent editions published.

Table 2.1-1

ITS User Services and Bundles

Bundle	User Services	Arizona Priorities	
		Urban	Rural
1. Travel and Transportation Management	1. En-route Driver Information	✔	Some
	2. Route Guidance	✔	
	3. Traveler Services Information	✔	
	4. Traffic Control	✔	✔
	5. Incident Management	✔	✔
	6. Emissions Testing and Mitigation		
2. Travel Demand Management	7. Demand Management and Operations	✔	
	8. Pre-trip Travel Information	✔	✔
	9. Ride Matching and Reservation		
3. Public Transportation Operations	10. Public Transportation Management		
	11. En-route Transit Information	✔	
	12. Personalized Public Transit		
	13. Public Travel Security		
4. Electronic Payment	14. Electronic Payment Services (Tolls)	Hold	
5. Commercial Vehicle Operations	15. Commercial Vehicle Electronic Clearance		✔
	16. Automated Roadside Safety Inspection	✔	✔
	17. On-board Safety Monitoring	✔	
	18. Commercial Vehicle Administrative Processes		✔
	19. Hazardous Materials Incident Response	✔	✔
	20. Freight Mobility	✔	✔
6. Emergency Management	21. Emergency Notification and Personal Security	✔	✔
	22. Emergency Vehicle Management	✔	Some
7. Advanced Vehicle Control and Safety Systems	23. Longitudinal Collision Avoidance		
	24. Lateral Collision Avoidance		
	25. Intersection Collision Avoidance		
	26. Vision Enhancement for Crash Avoidance		
	27. Safety Readiness (Electronic Signs)	✔	✔
	28. Pre-crash Restraint Deployment		
	29. Automated Highway System		

Table 2.1-2

Examples of Current ITS Deployments

System	User Service(s) Provided	Status
Transportation Management ▸ *Los Angeles Automated Traffic Surveillance and Control* ▸ *Seattle Freeway Management System* ▸ *Phoenix Freeway Management System* ▸ *Las Vegas Area Computer Traffic System*	▸ Traffic Control ▸ Incident Management	▸ Islands of ATMS deployment ▸ Limited deployment of video cameras ▸ Manual monitoring ▸ Primarily public sector influence
Travel Information ▸ *MetroTraffic* ▸ *ShadowTraffic* In-vehicle Route Guidance ▸ *Oldsmobile Guidestar* PC-based Software ▸ *City Streets*	▸ Pre-trip Travel Information ▸ En-route Driver Information ▸ Route Guidance ▸ Traveler Information Services	▸ Radio and TV broadcasts in most markets ▸ Limited deployment of route guidance ▸ Primarily private sector influence
AVL/AVI ▸ *Various Transit Systems* ▸ *Various Commercial Vehicle Operators* ▸ *Various Emergency Management Services*	▸ Public Transportation Management ▸ Commercial Fleet Management ▸ Emergency Vehicle Management	▸ Limited AVL applications/ scheduling software ▸ Limited AVI deployment ▸ Public and private sector influence
Electronic Toll Collection ▸ *Illinois State Toll Highway Authority* ▸ *Oklahoma PIKEPASS*	▸ Electronic Payment Services	▸ Limited/isolated deployment ▸ Public and private sector influence
Electronic Clearance ▸ *HELP, Inc.* ▸ *Advantage I-75 (Operational Test)*	▸ Commercial Vehicle Electronic Clearance	▸ Limited/isolated deployment ▸ Public and private sector influence
Collision Avoidance Systems ▸ *VORAD/Greyhound Bus Lines*	▸ Longitudinal Collision Avoidance ▸ Lateral Collision Avoidance	▸ Limited/isolated deployment ▸ Primarily private sector influence

No firm schedules for deployment are presented; instead 5-, 10-, and 20-year deployment visions are presented:

- 5-year: Era of Travel Information and Fleet Management (**Figure 2.1-1**).
- 10-year: Era of Transportation Management (**Figure 2.1-2**).
- 20-year and beyond: Evolution of transportation data collection, dissemination, and traffic management. Evolution to the Automated Highway System (AHS).

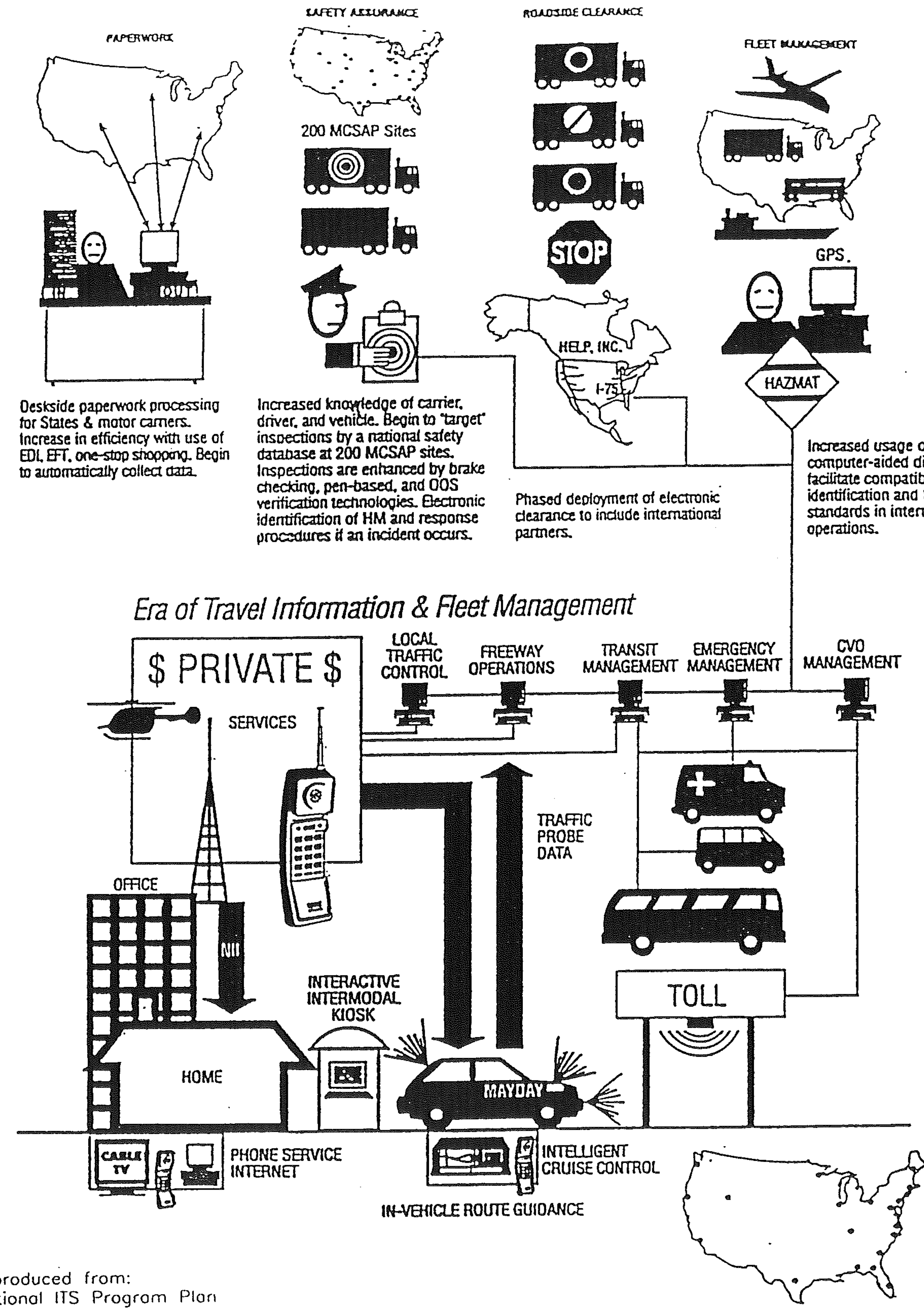
2.2 ARIZONA ITS REQUIREMENTS

Arizona is a state with widely divergent communities and communication infrastructures. As such, it will benefit greatly by implementing and integrating services. **Figure 2.2-1**, a map of the state, depicts major metropolitan areas, major freeways, major tourist attractions, significant CVO activity, and significant rural highways.

In terms of the National ITS Program Plan and based on guidance from the project Technical Advisory Committee, Arizona ITS requirement priorities are:

- Integrated metropolitan traffic control and incident management (ATMS).
- Rural and metropolitan Advanced Traveler Information Systems (ATIS).
- Rural emergency services.
- CVO services including significant border traffic across the Mexican border.
- Significant rural transit.
- A need to integrate existing FMS and signal systems into evolving ITS services.
- A communications and operations plan for location of TOCs for multiple ITS services.

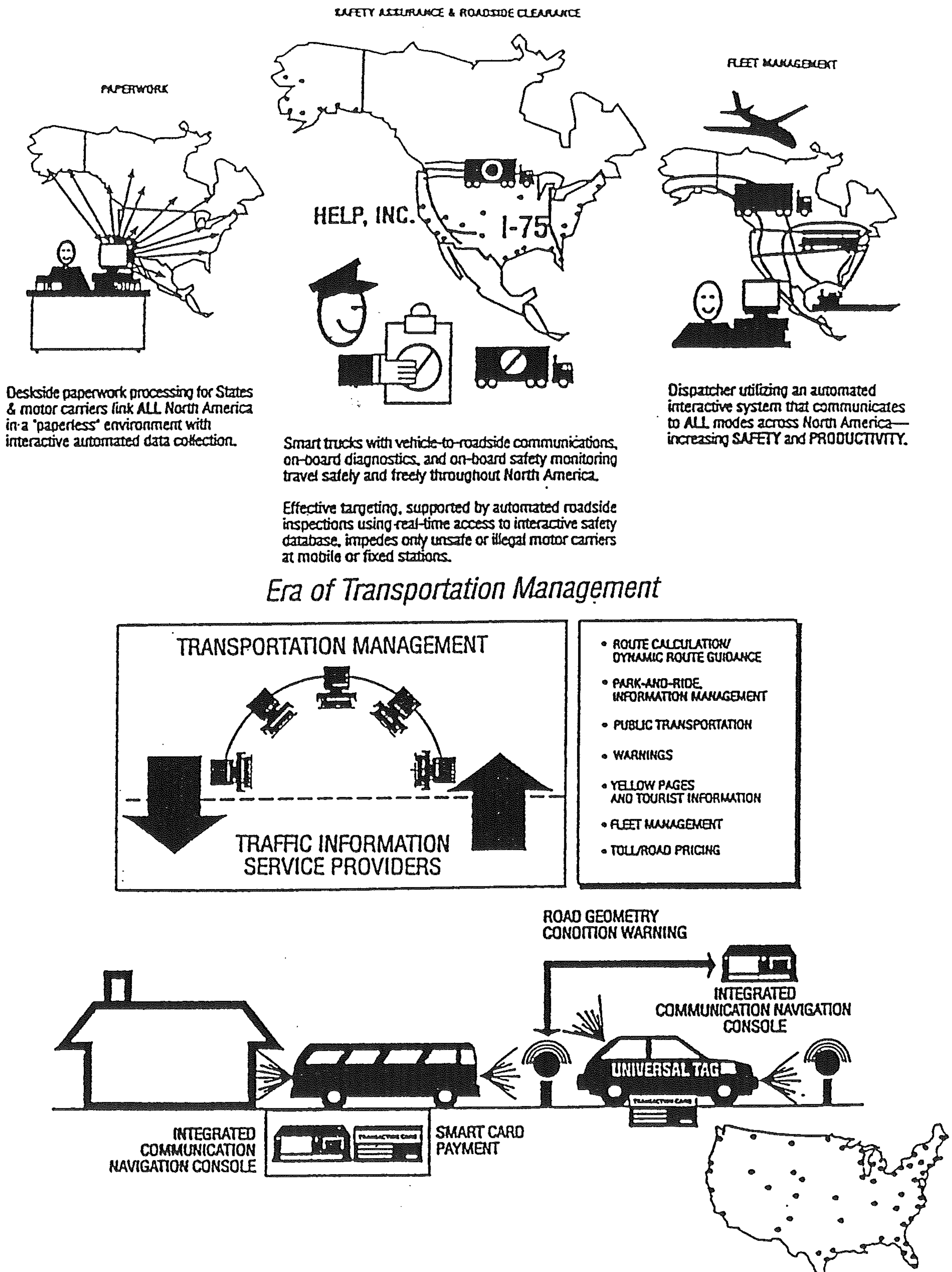
The two right hand columns in **Table 2.1-1** identify the specific ITS user services that the ADOT Technical Advisory Committee and KHA have jointly identified to address the above priorities.



* Reproduced from:
National ITS Program Plan

5 - Year Deployment Vision

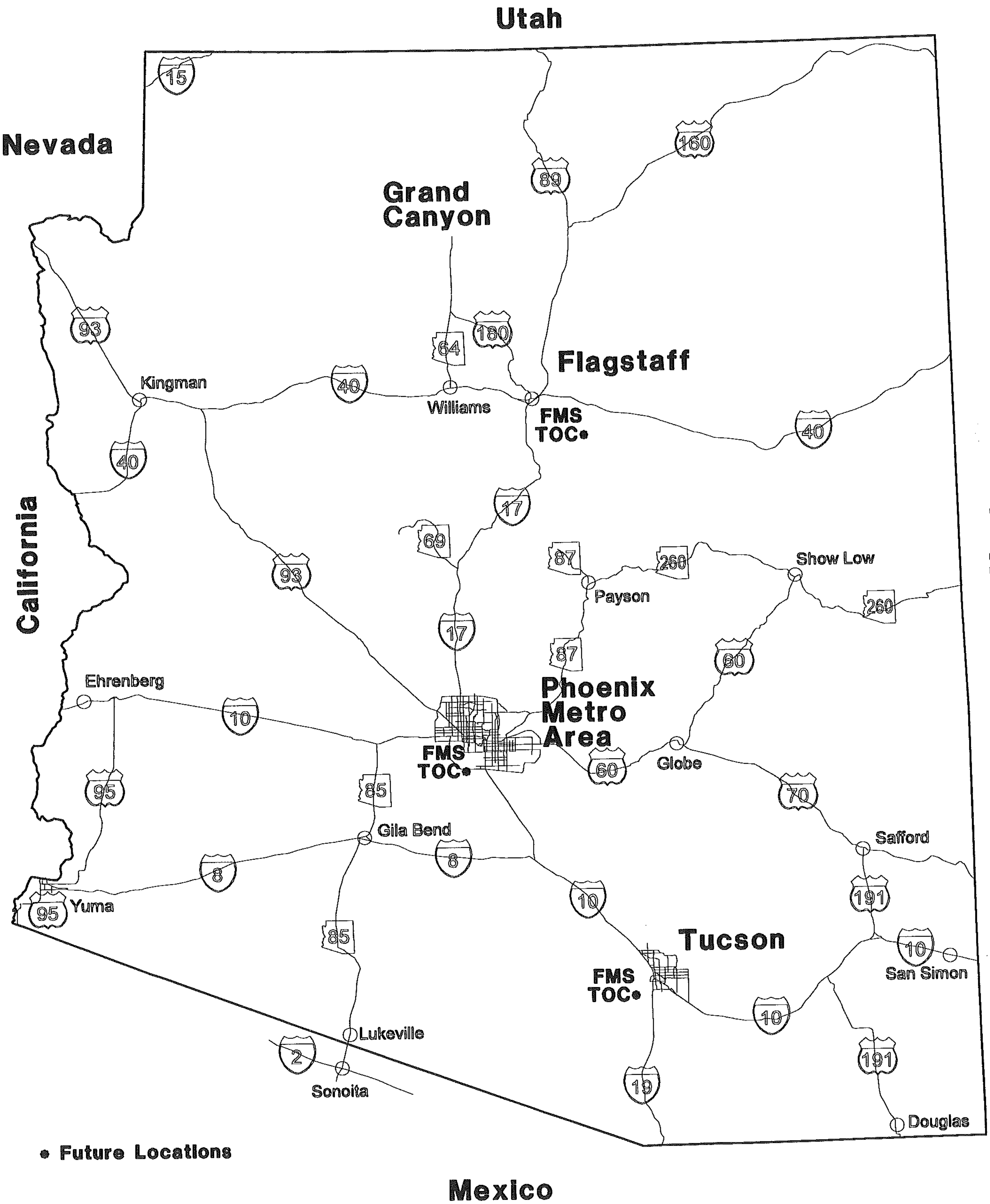
Figure 2.1-1



* Reproduced from:
National ITS Program Plan

10 - Year Deployment Vision

Figure 2.1-2



Significant Arizona ITS Requirements and Locations

Figure 2.2-1

3.0 EXISTING ADOT ITS-RELATED SERVICES

ADOT has already deployed equipment and systems that provide ITS-related functionality and that will require upgrades and/or enhancements to be part of a statewide integrated ITS system.

3.1 FMS SYSTEM - PHOENIX

ADOT is implementing a Freeway Management System (FMS) in the Phoenix metropolitan area. Currently, the system includes approximately 29 miles of freeway along I-10 and I-17. The system is designed to accommodate more than 200 miles of freeway in future expansion. It includes the following equipment:

- Loop detectors.
- Closed circuit television (CCTV) (approximately 1 mile spacing).
- Variable message signs.
- Ramp metering.
- Traffic interchange signals.
- Freeway drainage systems.
- Tunnel management system.

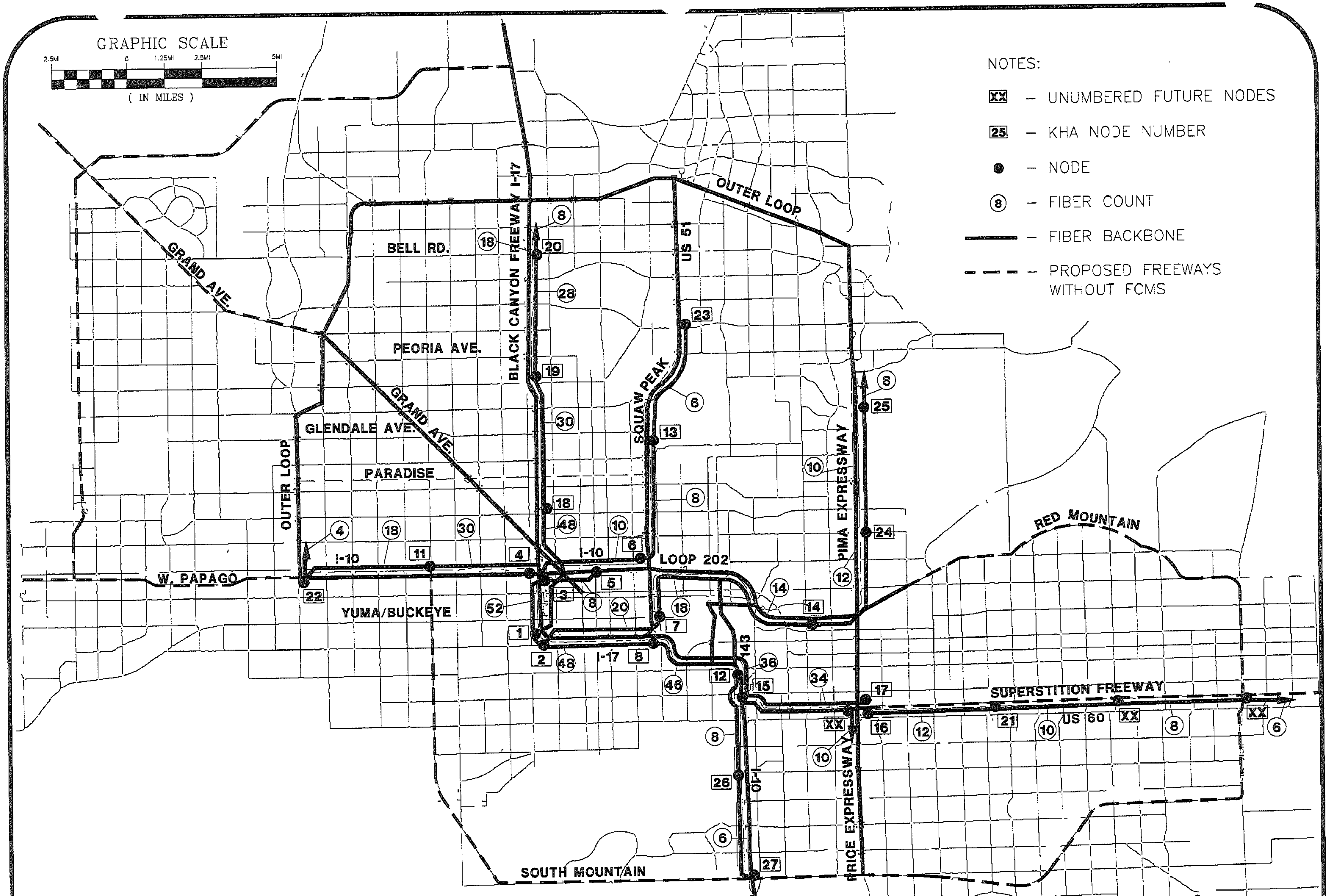
The field equipment communicates with the communications field nodes via fiber for the broadband video and via TWP for the low-speed data used by equipment controllers. Communication from the field nodes to the TOC is over fiber optic cable. A map of the freeway FMS is presented in **Figure 3.1-1**.

The TOC is equipped with:

- Operator workstations with both video and computer displays.
- A bank of video monitors to display field video.
- A video switch to route video to the appropriate monitor.
- A large screen graphic display for general status information.
- A Sun computer system.
- A communications subsystem that interfaces, controls, and manages field communication.

3.2 SIGNAL SYSTEMS

Arizona has numerous signal systems installed throughout the state. Most of the signal systems are owned and operated by local jurisdictions and are listed in **Table 3.2-1**. The state also owns and operates signal systems as listed in **Table 3.2-2**. **Figure 3.2-1** shows the location of signal systems in Arizona.



FMS Communication System
29 Miles Implemented, Over 200 Miles Planned

Figure 3.1–1

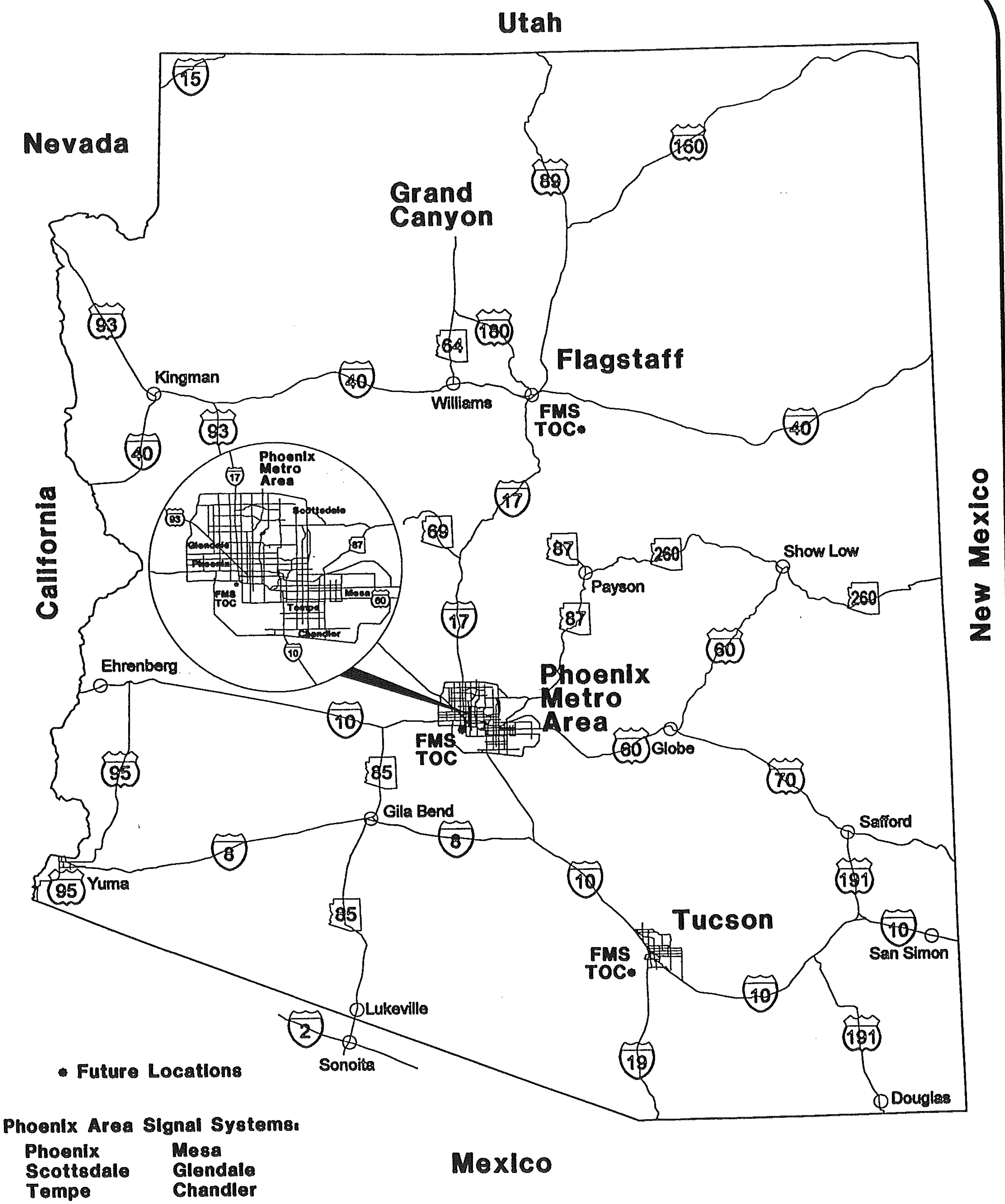
Table 3.2-1
Jurisdiction-owned Signal Systems (Coordinated)

Jurisdiction	Phoenix*	Scottsdale*	Tempe*	Mesa*	Glendale*	Chandler*	Tucson	Flagstaff	Maricopa County*
No. of Controllers	793	168	155	261	98	52	350	22	130
No. of Interconnected Controllers	481	150	148	247	6	43	350	5	0
Type of Controllers	NEMA Type 1	Model 170	NEMA Type 2	NEMA Type 1	NEMA Type 1	NEMA Type 1	NEMA Type 1 & 170	NEMA Type 1	NEMA Type 1
Applications Software	Computran UTCS	JHK 2000	Computran UTCS	SONEX	TRANSYT Closed Loop	Eagl- Marc Closed Loop	JHK 2000	Eagle Closed Loop	Closed Loop
Type of Communications	Telco	Telco	Telco	Telco	TWP	TWP	TWP & Telco	TWP & Microwave	TWP

*Phoenix Metropolitan Area

Table 3.2-2
State-owned Signal Systems

Jurisdiction	FMS	Maricopa County	Flagstaff
No. of Controllers	14	130	20
No. of Interconnected Controllers	14	19	20
Type of Controllers	Model 179	NEMA Type 1	NEMA Type 1
Applications Software	KHA	Econolite / Eagle	Econolite
Type of Communications	TWP / F-0	TWP / Telco	TWP



Map of Locations of Arizona Signal Systems

Figure 3.2–1

The long range ADOT communications infrastructure plan should include strategies for enhancing these systems so that they can be integrated into a statewide integrated ITS system. In many cases, these signal systems control arterials adjacent to freeways and are an important resource for effective integrated ATMS operations.

3.3 WIM/AVC

A number of Weigh-in-Motion (WIM) and Automated Vehicle Classification (AVC) sites have been installed in Arizona in connection with the HELP/Crescent project and pavement test sites of the Strategic Highway Research Program (SHRP).

There are six such WIM/AVC sites, installed as part of the HELP/Crescent project. They are listed in **Table 3.3-1** and shown in **Figure 3.3-1**. These stations have an integrated computer that collects raw data and creates statistics on operations.

All SHRP stations are operated and maintained by ADOT's Research Center. Periodically, traffic data are gathered from these sites via telephone-modem link. The locations of these stations are listed in **Table 3.3-2** and depicted on the map in **Figure 3.3-1**.

Table 3.3-1

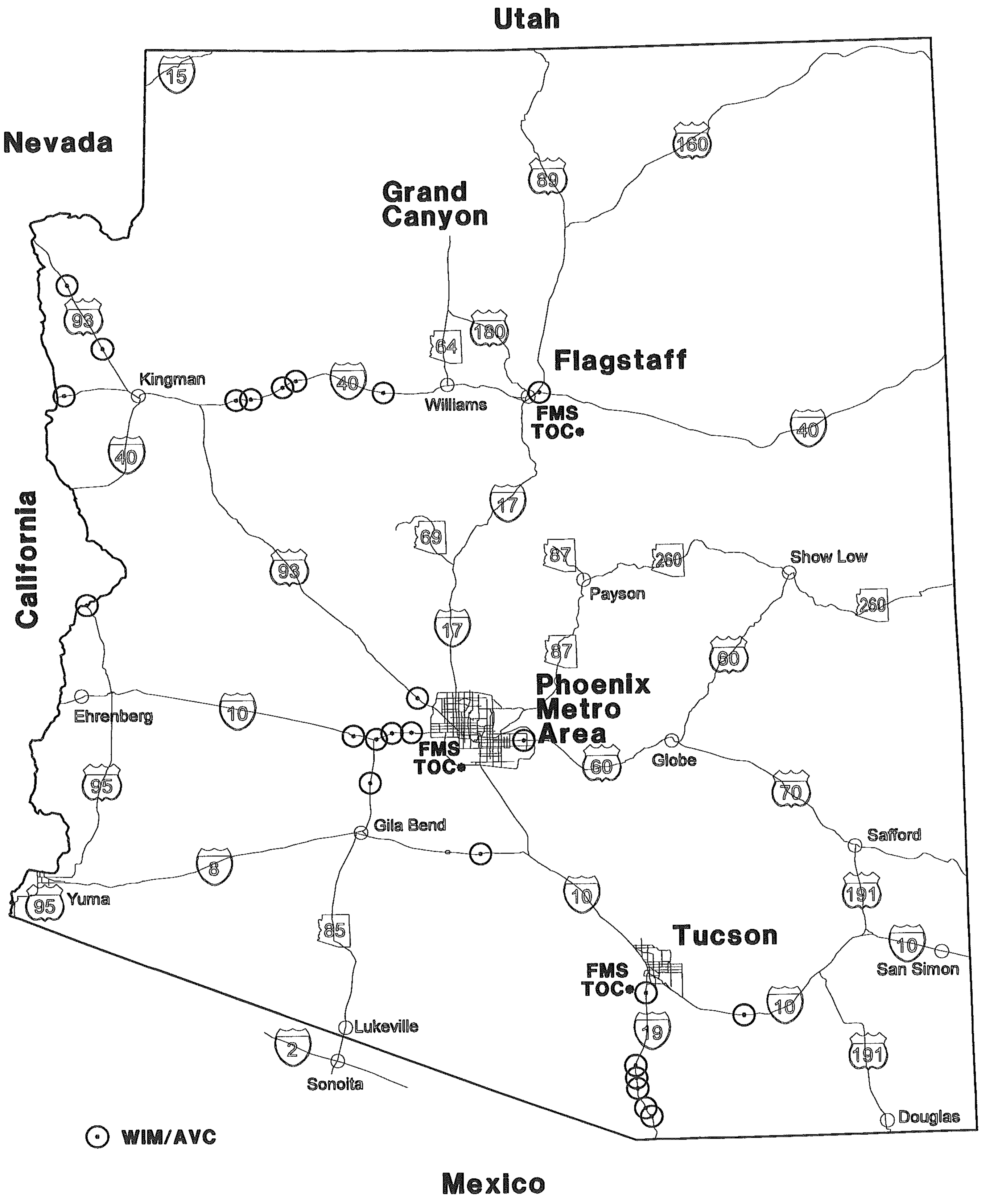
HELP WIM/AVC

1.	Ehrenberg Port of Entry	-	Milepost 4.0
2.	San Simon Port of Entry	-	Milepost 391.1
3.	Marana	-	Milepost 237.2
4.	Phoenix	-	Milepost 154.1
5.	Tonopah	-	Milepost 94.7 (partially operational)
6.	Benson	-	Milepost 300.1 (partially operational)

3.4 AUTOMATIC TRAFFIC RECORDER (ATR)

ADOT's Transportation Planning Division has a network of Automated Traffic Recorders (ATR) installed or proposed at approximately 31 sites. The purpose of these sites is to:

- Count vehicle traffic.
- Classify vehicles.
- Determine vehicle speed (at selected sites).



Locations of ATRC WIM/AVC Sites

Figure 3.3–1

Table 3.3-2

SHRP WIM/AVC Sites Operated by ATRC

AZ site #	SHRP ID	Location	Remarks
26	XX	I-10 MP 108 EB	
12	1006	I-10 MP 110.7 WB	
11	1007	I-10 MP 115.4 WB	
23	1001	I-10 MP 123.4 WB	
22	7614	I-10 MP 130.4 WB	
02	6053	I-10 MP 292.9 EB	
06	6060	I-19 KM 23.9 NB	
05	1015	I-19 KM 29.6 SB	
04	1016	I-19 KM 38 SB	
07	1017	I-19 KM 54.7 NB	
03	1018	I-19 KM 58.8 SB	
08	6054	I-19 KM 84.3 SB	
202	0600	I-40 MP 202 EB	
204	0600	I-40 MP 202 WB	
18	1024	I-40 MP 106.8 EB	
19	1025	I-40 MP 113.2 WB	
20	1002	I-40 MP 145.5 WB	
16	1062	I-40 MP 92.9 WB	
17	1065	I-40 MP 998.1 EB	
09	5000	I-8 MP 159.5 EB	
21	7079	SR-417 (LP 101) MP 11 NB	
15	1037	SR-68 MP 1.3 EB	
10	6055	SR-85 MP 141.9 SB	
13	1034	SR-95 MP 145.1 SB	
01	7613	US-60 MP 179 WB	
25	0100	US-93 MP 52.7 NB	
14	1036	US-93 MP 26.5 NB	

Figure 3.4-1 is a map showing the locations of these sites and **Table 3.4-1** lists these locations.

3.5 CALL BOXES

ADOT has installed 12 Emergency Phone Call Boxes using cellular telephones along I-19 on the route between Tucson and Green Valley. The purpose of these call boxes is to aid motorists in emergency situations. When employed, the cellular calls are directed to the Department of Public Safety. The locations of these call box sites are depicted in **Figure 3.5-1**.

3.6 SCAN® SITES (WEATHER DATA)

ADOT has installed 7 remote, computer-based, weather stations along I-40 in northern Arizona depicted in **Figure 3.6-1**. These weather stations collect data on:

- Temperature.
- Dew point.
- Wind speed and direction.
- Precipitation.
- Visibility.
- Road freeze point.
- Road temperature.
- Chemical content of moisture on roadway.

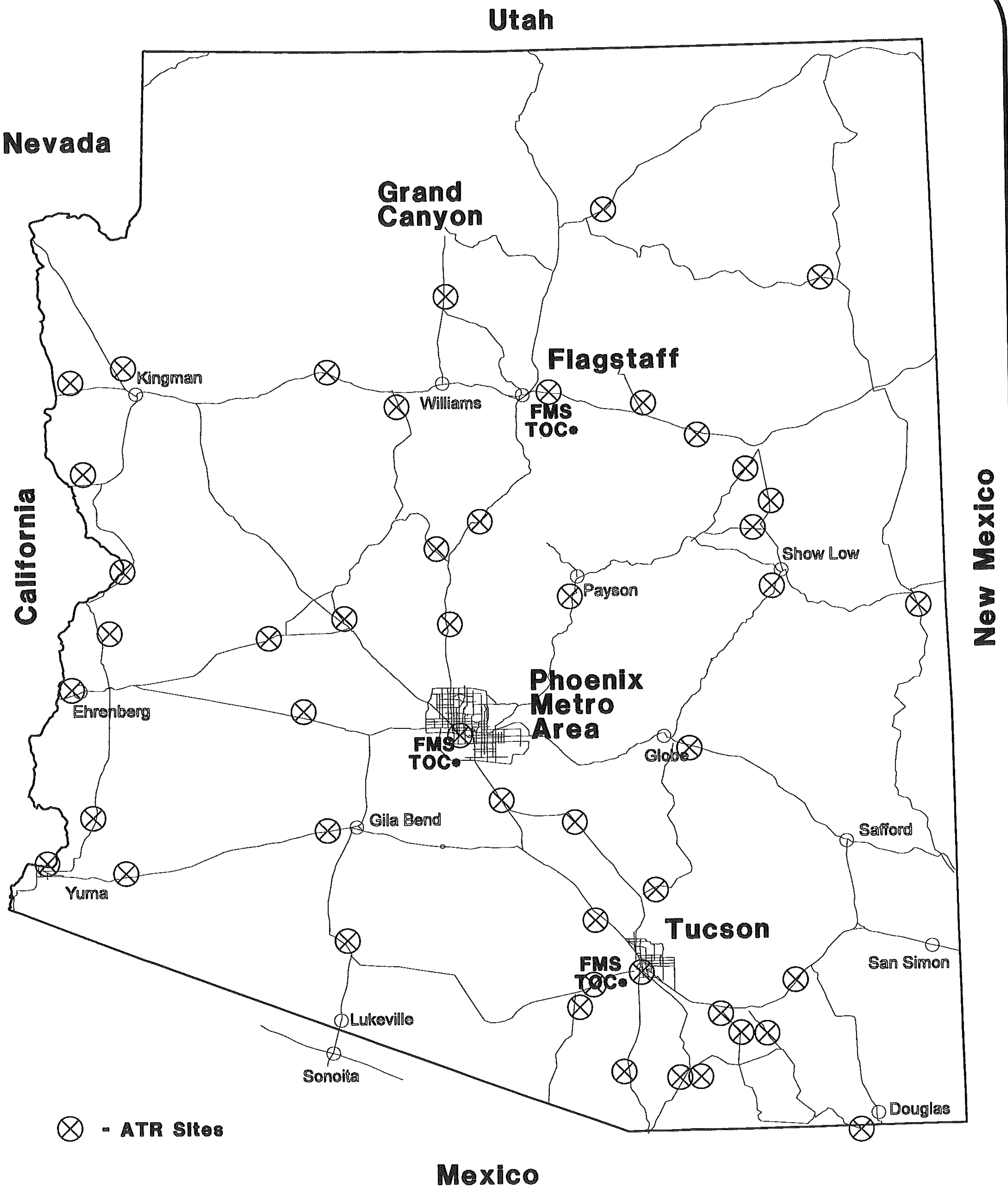
Locations along this route are subject to low visibility due to fog, rain, or snow; and to ice/snow conditions.

This data is communicated from the remote sensors via radio to a nearby microwave tower then into ADOT's microwave system and ultimately to ADOT offices in Flagstaff and Prescott. This information is currently used by maintenance personnel to assist in snow removal; however, the same information could be used to advise motorists of roadway conditions.

3.7 ELK CROSSING SIGNS

Variable Message Signs (VMS) are located on some routes where elk crossings occur to alert motorists during times of potential high crossing activity and for other conditions such as ice, fog, etc. These signs are located along State Route 260 northeast of Phoenix.

These are controlled from the ADOT TOC in Phoenix via dial-up telephone lines using modems. The locations of these signs are depicted on the map in **Figure 3.7-1**.



Proposed ATR Sites

Figure 3.4-1

Table 3.4-1

Proposed ATR Station Sites Classification
Leg Number by Station Number

Leg Number	Station Number	Location	Route
1	1	Thomas Road	SL 303
2	7	Flagstaff	I-40
3-4	15	Flagstaff	SR 89A
5-6-7-8	8	Phoenix	
9-10-11	20	Apache Jct.	US 60
12-13-14	22	Globe	US 70
15-16-17	34A	Gila Bend	I-8, B-8
18	251	McClintock	US 60
19-20-21-22	253	Quartzite	I-10, US 95
23-24-25	254	Wickenberg	SR 89, US 93
26-27-28	257	Topock	I-10, ST 95
29-30-31-126	259	Kingman	I-40, SR 66
32-33-34	260	Ashfork	I-40, SR 89
35-36-37	265	Show Low	US 60, SR 77
38-39-40	267	Prescottt	US 89, SR 69
41-42-43	270	Yuma	I-8, US 80
44	276	Nogales	SR 82-89
45-46-47	278	Mt. View	I-10, SR 83
48-49-50	281	Willcox	I-10, SR 191
51	287	Littlefield	I-15, MP 9.8
52-53-54	289	Kingman	US 93, SR 68
55-56-57	290	Cordes Jct.	I-17, SR 69
58	301	Yuma	US 95, Co. 14

Table 3.4-1 (cont'd)

Proposed ATR Station Sites Classification
Leg Number by Station Number

Leg Number	Station Number	Location	Route
59-60-61	302	Ajo	SR 85, SR 86
62-63-64	303	Toltec	I-8, I-10
65-66-67-68	304	Casa Grande	SR 84-287-387
69-70-71-72-73	305	Casa Grande	I-10, SR 187-387
74	306	Tucson	I-10
75-76-77	307	Tucson (S)	I-19, B19
78-79-80	308	Pearce (E)	SR 181, US 191
81-82-83	309	Winkelman	SR 77, SR 177
84-85-86	310	Eagar	SR 260, SS 260
87-88-89	311	Heber	SR 277, SS 260
90-91-125	312	Winslow	SR 87, SR 99
92-93-94	313	Holbrook	I-40, SR 77
95-96-97	314	Keam's Canyon	SR 264-87
98-99-100	315	Kayenta	US 160-163
101-102-103	316	Tuba City	US 160, SR 264
104-105-106	317	Cameron	US 89, SR 64
107-108-109	318	Flagstaff	B-40, US 180
110-111-112	319	Bitter Springs	US 89-89A
113-114-115	320	Valle	SR 64, US 180
116-117-118	321	Jacob Lake	US 89A, SR 67
119-120-121	322	Davis Dam	SR 68-95

Table 3.4-1 (cont'd)

Proposed ATR Station Sites Classification
Leg Number by Station Number

Leg Number	Station Number	Location	Route
122-123-124	323	Ganado	SR 264-191
127-128-129		Buckeye	SR 85
130		99th Avenue	SR74
131		San Luis	SR 95
201-202		Nogales	SR 189

3.8 ARIZONA PORTS OF ENTRY

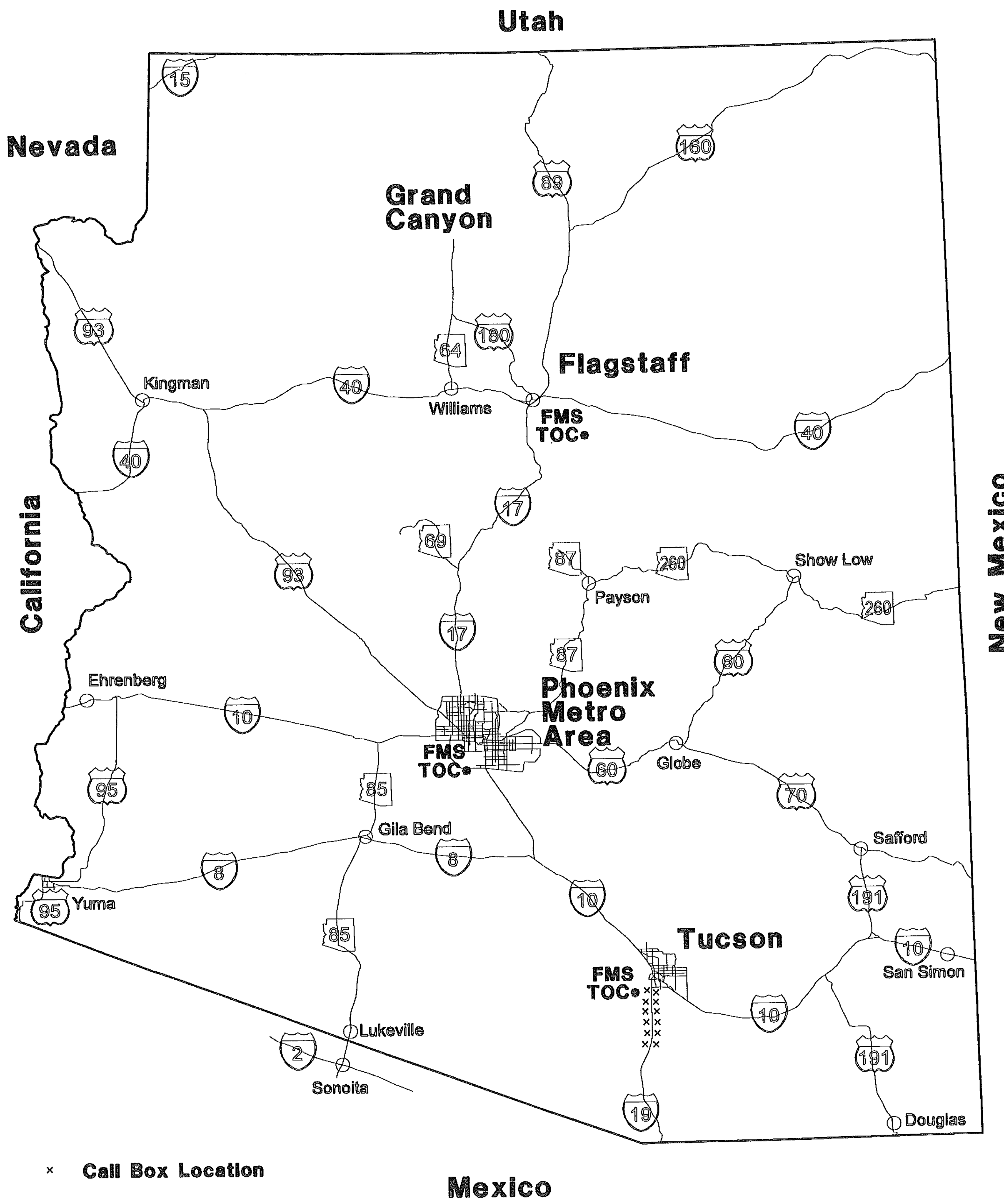
Arizona has 17 Ports of Entry on the California, Nevada, Utah, New Mexico, and (International) Mexico borders. The Ports of Entry are listed in **Table 3.8-1**. These ports are manned and operated by ADOT

3.9 RADIO BROADCAST DATA SYSTEMS (RBDS)

ADOT has a Memorandum of Agreement (MOA) with several public/private partners for an Advanced Travelers Information System (ATIS) demonstration project in the Phoenix metropolitan area that will employ RBDS.

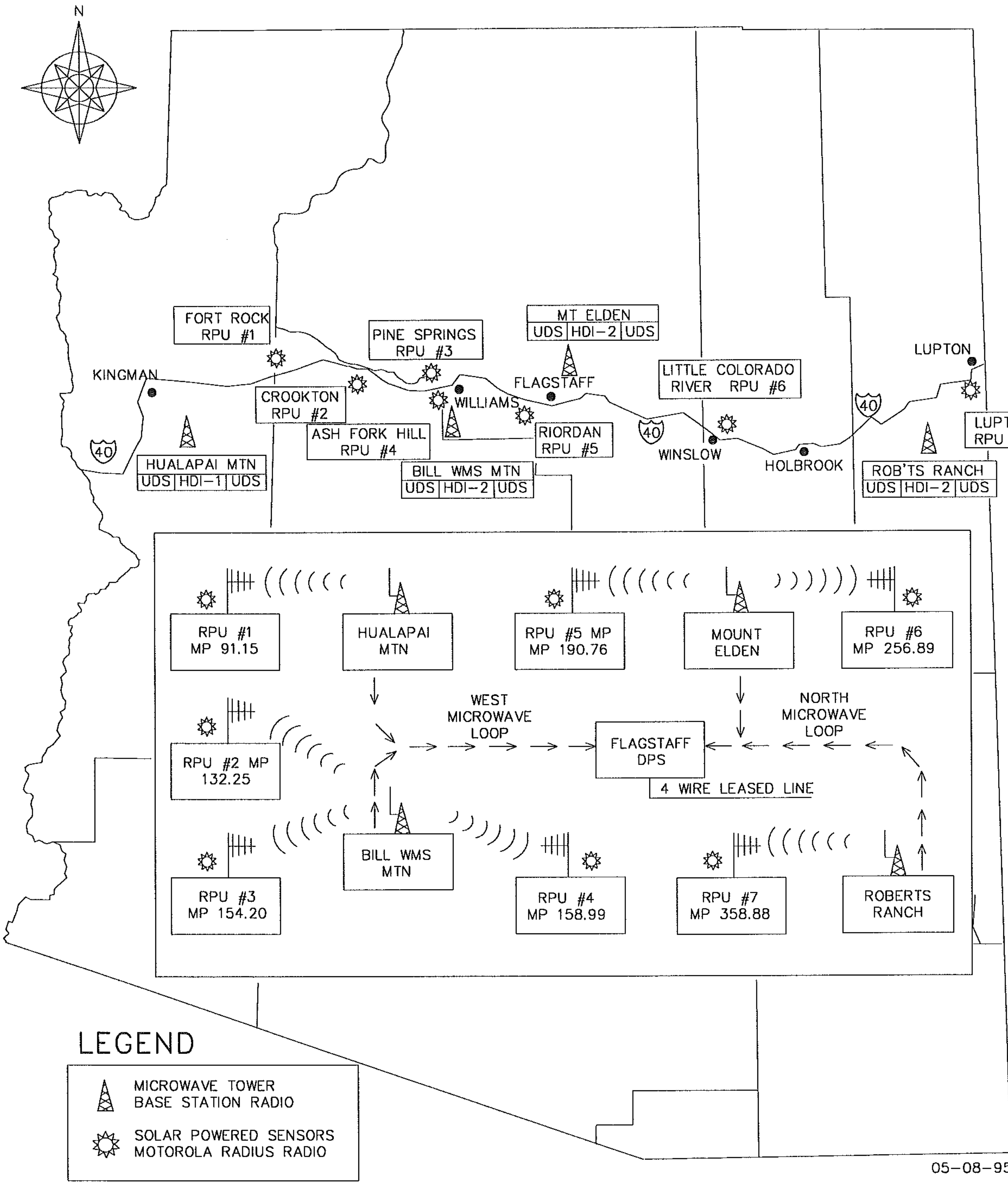
RBDS operates as a subcarrier over existing FM radio stations. FM radio stations operate in the 88-108 MHz band on channel spacings of 200 kHz. This spacing provides bandwidths greater than required for high quality stereo audio. Thus, portions of this bandwidth (see **Figure 3.9-1**) can be allocated for digital data transmission with wide-area coverage essentially the same as the FM audio coverage area. In fact, standard radio receivers can be equipped with an RBDS interface or an integrated RBDS data decoder.

This demonstration project has selected Scottsdale radio station KSLX FM (100.7 MHz), which has its antenna located on South Mountain, and is a 100-kilowatt station with a 50-mile radius coverage area.



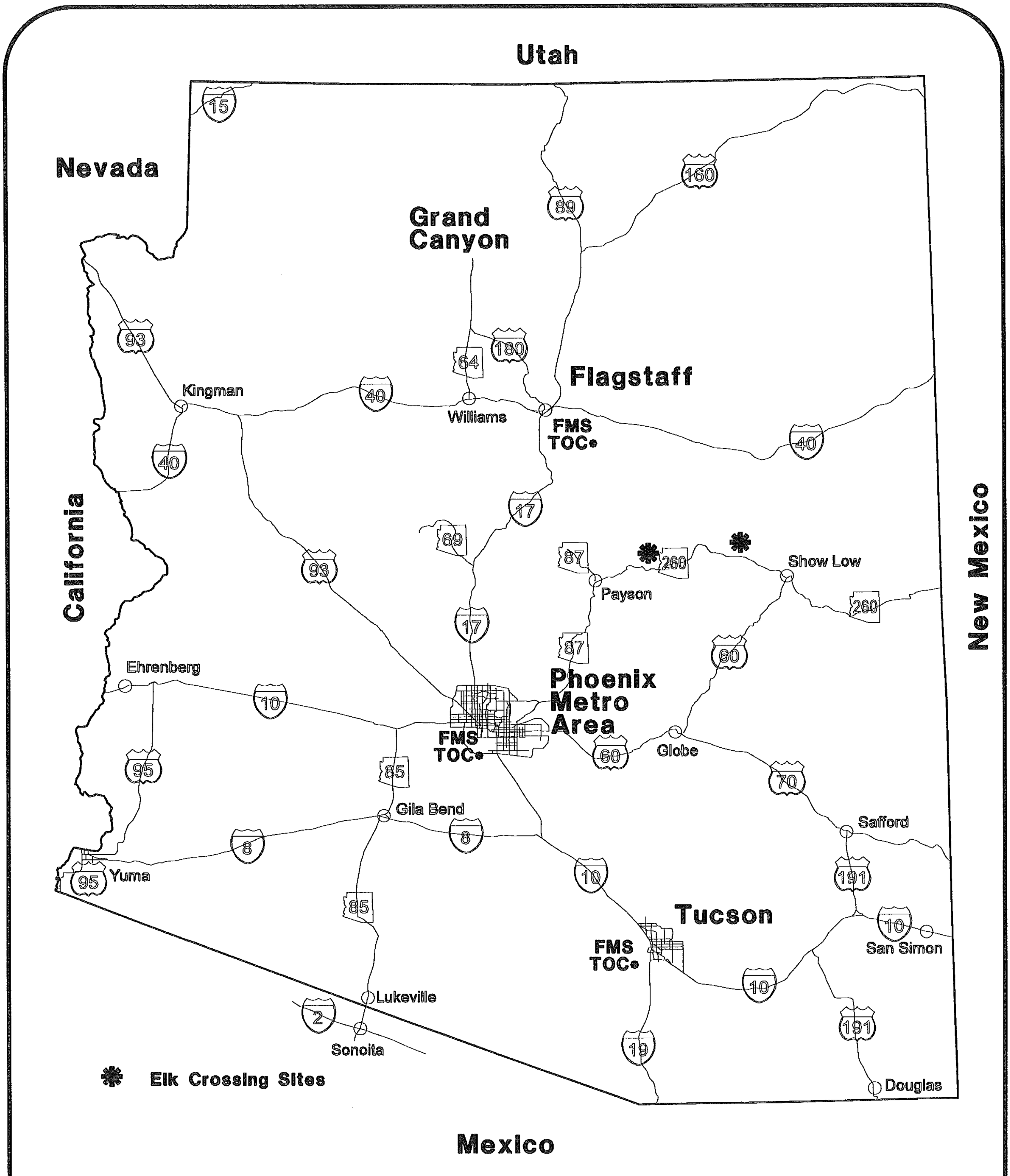
Call Box Locations

Figure 3.5–1



ADOT Districts Kingman, Flagstaff, and Holbrook Ice Warning System

Figure 3.6-1



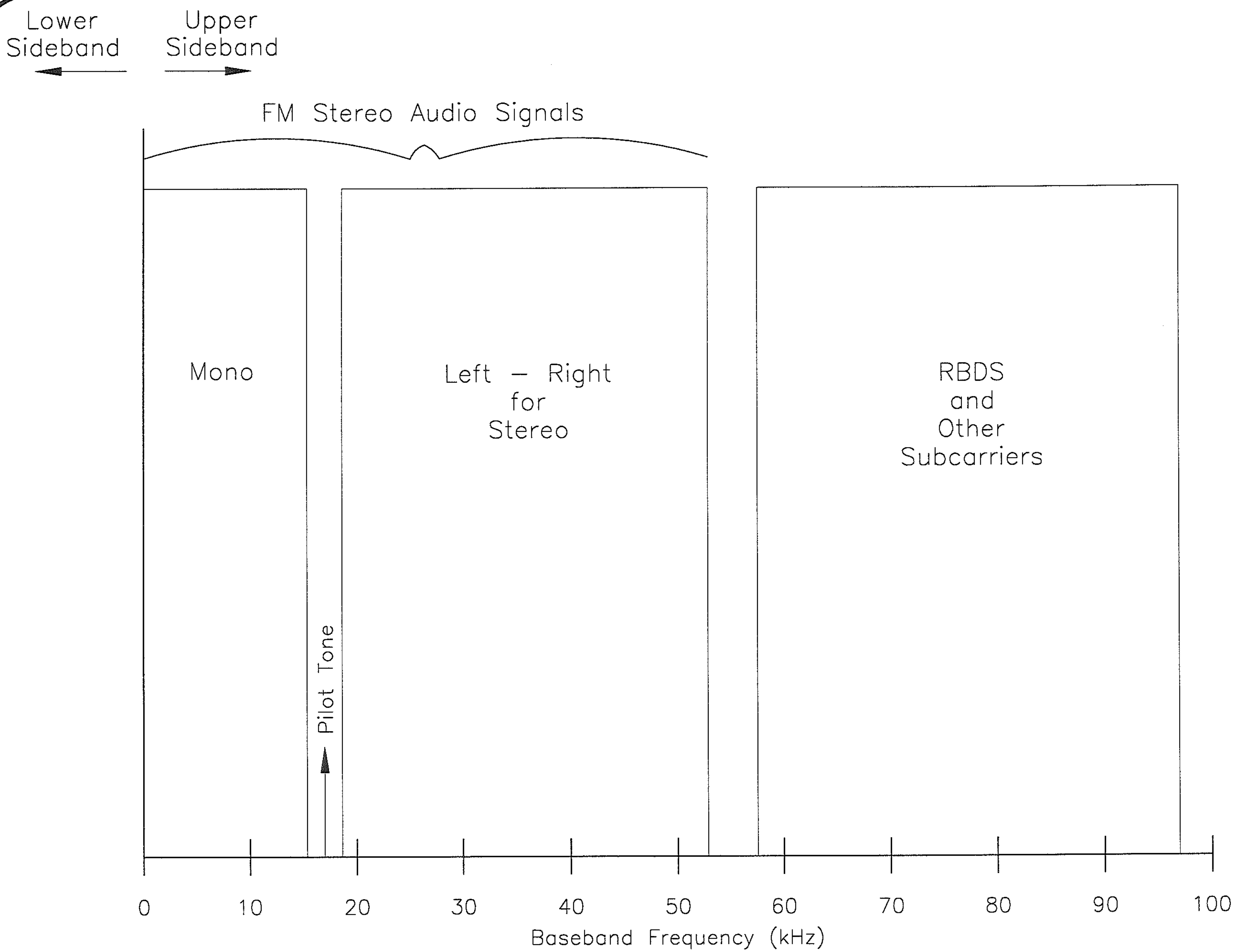
Locations of Elk Crossing Signs

Figure 3.7–1

Table 3.8-1

Arizona Ports of Entry

ADOT Org.	Location	Address	Phone #
2166	Douglas (S)	P.O. Box 875 Douglas 85608-0875	364-5011
2163	Duncan (S)	P.O. Box 175 Duncan 85534-0175	359-2562
2156	Ehrenberg (C)	P.O. Box 270 Ehrenberg 85334-0270	927-6652
2149	Fredonia (N)	P.O. Box 367 Fredonia 86022-0367	643-7096
2152	Kingman (C)	P.O. Box 549 Kingman 86402-0549	753-1465
2165	Nogales (S)	P.O. Box 1827 Nogales 85621-1827	287-3861
2148	Page (N)	P.O. Box 1807 Page 86040-1807	645-3269
2153	Parker (C)	310 California Avenue Parker 85344-4477	669-2534
2145	St. George (N)	P.O. Box 956 St. George UT 84770	801/673-3786
2142	Sanders (N) MP 340, I-40	P.O. Box 99 Sanders 86512-0099	688-2579
2161	San Luis (S) MP 01, SR 95	P.O. Box 449 San Luis 85349-0415	627-2970
2162	San Simon (S)MP 383.3, I-10	P.O. Box 68 San Simon 85632-0068	845-2280
2147	Springerville (N) P.O.E. & D/L	P.O. Box 209 Springerville 85938-0209	333-4415
2141	Teec Nos Pos (N)	P.O. Box 267 Teec Nos Pos 86514-0267	656-3214
2154	Topock (C) MP 3, I-40	P.O. Box 549 Kingman 86402-549	768-3756
2143	Window Rock (N)	Box 148 Window Rock 86515-0148	871-4274
2169	Yuma (S)	P.O. Box 5733 Yuma 85366-5733	783-5141



Baseband FM Spectrum Illustrating RBDS Subcarrier

Figure 3.9–1

The purpose of the demonstration project is to test equipment and concepts for wide-area ATIS that will provide travelers with accurate real-time information that will permit them to make more informed transportation decisions. This real-time information could include the following:

- Weather conditions.
- Known congestion based on FMS surveillance data and other sources.
- Known incident locations.
- Recommended routes.
- Others to be determined.

This information will be coded in International Traveler Information Interchange Standards (ITIS), which is a standard protocol for coding location and traveler-related events. The information may be shown in graphics on an in-vehicle navigation system, or in text on a small LCD display, or maybe broadcast as an audio message, depending on the type of receiver. Receivers may be in vehicles or at fixed locations.

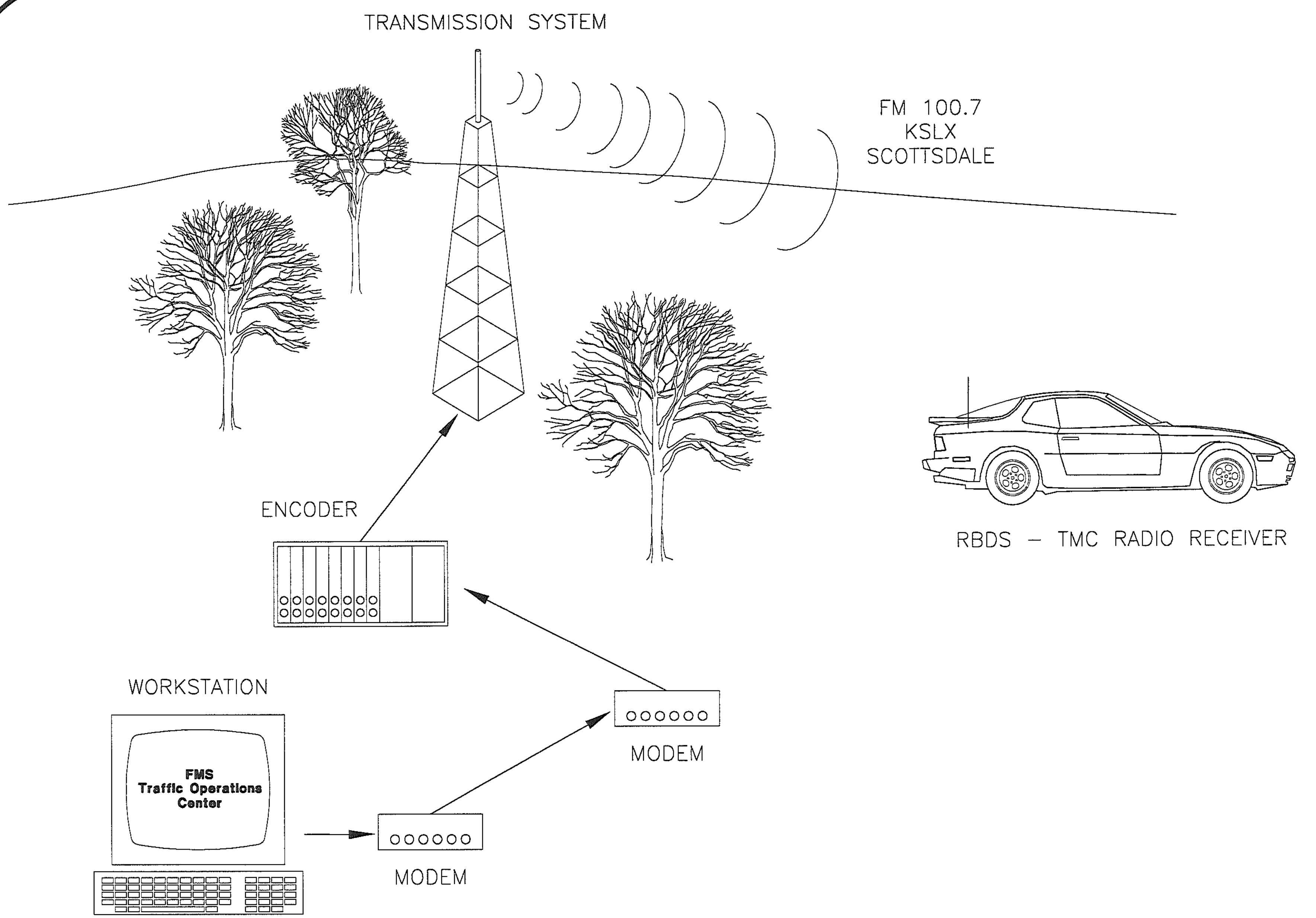
A block diagram of the anticipated demonstration system is presented in **Figure 3.9-2**.

3.10 EXPEDITED PROCESSING AT INTERNATIONAL CROSSINGS (EPIC)

A Field Operational Test (FOT) on Expedited Processing at International Crossings (EPIC) is planned at crossings in Nogales, Arizona. The FOT is sponsored by ADOT, FHWA, and private sector partners led by Lockheed IMS.

The goals of EPIC have been defined in meetings that involved Nogales businesses, trucking industry representatives, and Mexico's local and national officials. The goals are to expedite commercial vehicle travel across the border while maintaining/enhancing U.S. safety and regulatory requirements.

EPIC will use various "smart highway" technologies such as Automated Vehicle Identification (AVI) through transponders and readers, Weigh-in-Motion (WIM), Traffic Management Systems (TMS), License Plate Recognition (LPR), and digital photography to reach its goals. The project team consists of U.S. Customs, INS, USDA, FDA, and other related parties such as ADUANAS, SCT, brokers, shippers, truckers, and other private partners.



Block Diagram of RBDS System Demonstration Project

Figure 3.9–2

4.0 PLANNED ITS SERVICES

On-going plans and programs for delivering future ITS services in Arizona include:

- FMS expansion in the Phoenix Metro area.
- FMS for Tucson area.
- Flagstaff TOC.
- MAGIC/Maricopa County.
- Statewide VMS/RWIS programs.

4.1 PIMA COUNTY/TUCSON AREA FMS

The Pima Association of Governments has commissioned and completed a study for an FMS system along I-10 and I-19 to equip approximately 30 miles of highway in the Tucson area. Plans for implementation are on going in conjunction with current and planned freeway reconstruction.

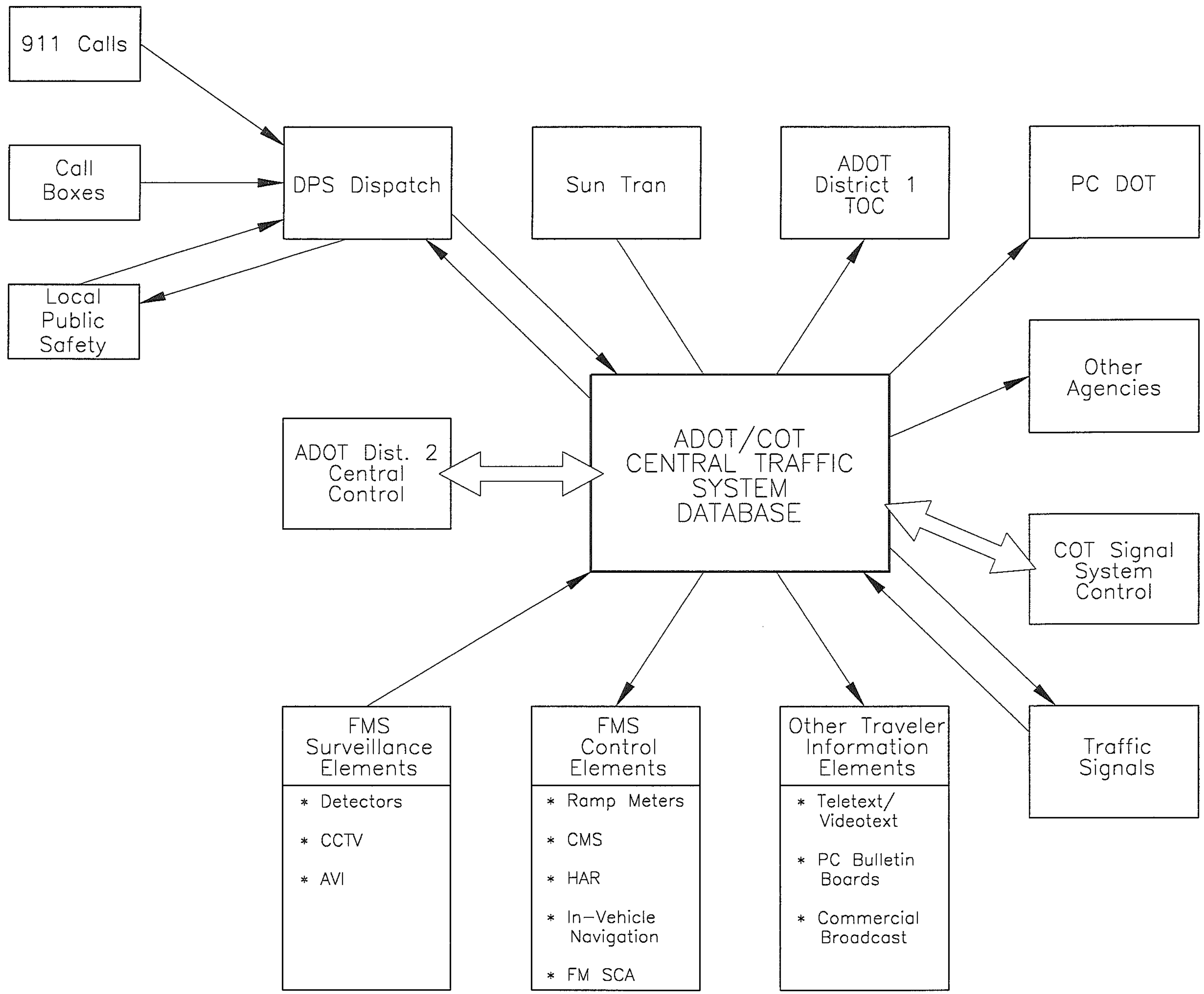
Included in this planning process are needed modifications to the existing freeway management organizational structure. The general functions identified for inclusion in the PAG/ADOT FMS include:

- Congestion Management.
- Incident Management.
- Traveler Information (ATIS).
- Commercial Vehicle Operations (CVO).
- Ancillary Functions.

All of the above functions require installation of various equipment along the freeway to monitor the status, provide control, inform travelers, collect statistical data, etc. A communications infrastructure is required to interconnect the various sources and sinks (destinations) of data. The Pima FMS plans identify the following for implementation to provide the above services:

- Ramp metering.
- Vehicle detectors (volume, speed, occupancy, and vehicle classification).
- CCTV cameras (general surveillance and incident detectors).
- Traveler information (HAR, commercial TV and radio broadcast, call-in service, VMS, etc.).

The proposed FMS organizational structure to implement these capabilities is presented in **Figure 4.1-1**.



Proposed PAG/ADOT FMS Organizational Structure

Figure 4.1-1

4.2 FLAGSTAFF FMS

Flagstaff is at the center of the I-40 corridor that stretches from the New Mexico border on the east and the California border on the west. This corridor covers approximately 359 miles and is characterized by:

- Significant CVO traffic.
- Significant weather-related problems in the winter.
- Historical/tourist attractions including Grand Canyon National Park, Painted Desert, Petrified Forest National Park, Walnut Canyon National Mounment, etc.
- Alignment with historical Route 66.
- Junction with I-17 and US 89 and US 180.

Nationally, this corridor is recognized as an excellent trailblazer and test bed for rural ATIS with Flagstaff serving as the TOC location.

The entire corridor is managed by three (3) ADOT District Offices in Kingman, Flagstaff, and Holbrook. Other important facilities along the interstate corridor include:

- Rest areas (3 eastbound, 4 westbound).
- Two ports of entry at the New Mexico and California borders to deal with permits and fees.

Of critical concern for the corridor is the level of safety. During winter, portions of the corridor are affected by snow, ice, wind, and high CVO traffic conditions. Fog can occur year round at certain locations as can smoke from controlled forest burns that restrict visibility. Commercial vehicle traffic constitutes 40% of the traffic. Seventy (70) to 80 percent of that is through traffic, creating long stretches of potentially unsafe continuous driving conditions.

The number of visitors to the state's tourist attractions is becoming significant enough to motivate discussions on vehicle restrictions in the Grand Canyon area and includes considerations of rural transit service.

Existing ITS-related systems include the previously discussed SCAN weather systems and WIM/AVC devices. The Flagstaff Chamber of Commerce installed an information system, named "Flagstaff Infoguide," to provide tourists with information on local attractions and events. This system has been decommissioned because the technology involved became outdated. The National Park Service and the National Forest Service have on-going efforts to implement a similar system. Longer range planning includes installation of Tourist Information Terminals at kiosks located in rest areas along I-40.

The corridor presents an excellent opportunity for integrated rural ITS as it involves multiple stakeholder agencies:

- Department of Public Safety.
- Governor's Office of Highway Safety.
- Metropolitan Planning Organizations and Councils of Governments.
- State Bureau of Tourism.
- Flagstaff Chamber of Commerce.
- National Park Service.
- National Forest Service.
- Navajo and Hopi Nations.
- Commercial Vehicle Operators.

A preliminary review indicates that most ITS services will be in bundles 1 and 5 (see **Table 2.1-1**) of the National ITS Program Plan and will provide significant information on rural ITS architecture requirements. The potential needs and solutions include:

- A system for dissemination of information on weather conditions
- Impaired visibility detection systems
- Use of closed circuit television cameras for security at rest areas
- A system for reporting maintenance and construction activities
- Development of a northern Arizona Traffic Operations Center (TOC).
- Identification of alternatives based on current and emerging technologies
- Improved operations at Ports of Entry
- Highway Advisory Radio (HAR) broadcasts.

4.3 MAGIC/MARICOPA COUNTY

Existing ITS-related programs have focused on individual ITS-related systems such as freeway management systems, signal systems, etc., often with minimal integration among these subsystems. The ITS vision requires that these services be integrated to promote efficient transportation management and traffic flow on freeways and adjacent arterial streets. A Maricopa Regional Information Center (MAGIC) program was initiated in 1993 involving 12 agencies and municipalities in the Maricopa/Phoenix area:

- City of Phoenix.
- City of Mesa.
- City of Tempe.
- City of Scottsdale.
- City of Glendale.
- City of Peoria.
- City of Chandler.

- City of Gilbert.
- City of Paradise Valley.
- Maricopa County.
- Regional Public Transportation Authority.
- ADOT.

The goal of MAGIC is to integrate the FMS system with signal systems of the individual municipalities. This integration must continue to support the local requirements of municipalities as well as provide expanded functionality to make regional travel more efficient. The program includes three concepts:

Phase 1	Signal Systems.
Phase 2	Advanced Traffic Management Systems (ATMS).
Phase 3	Advanced Traveler Information Systems (ATIS).

Recent work has resulted in a recommended communications architecture which will be discussed later in this document.

5.0 EXISTING COMMUNICATION INFRASTRUCTURE

Certain communication infrastructure facilities already exist within ADOT and long range plans should consider their utility. The following systems have been identified:

- ADOT, statewide WAN.
- ADOT, radio systems.
- FMS communication subsystem.

5.1 ADOT WAN NETWORK

ADOT has a Wide Area Network (WAN) that interconnects Local Area Networks (LANs) at various ADOT sites around the state. **Figure 5.1-1** presents a high level summary of the network. The network consists of bridges, routers, and the various local LAN networks. The network is interconnected by commercial DS-1 (1.544 Mbps) circuits and some private wire and fiber in the Phoenix area.

5.2 ADOT RADIO AND MICROWAVE SYSTEM

ADOT has three radio systems maintained by Arizona's Department of Public Safety (DPS) which provided information on the systems' capabilities.

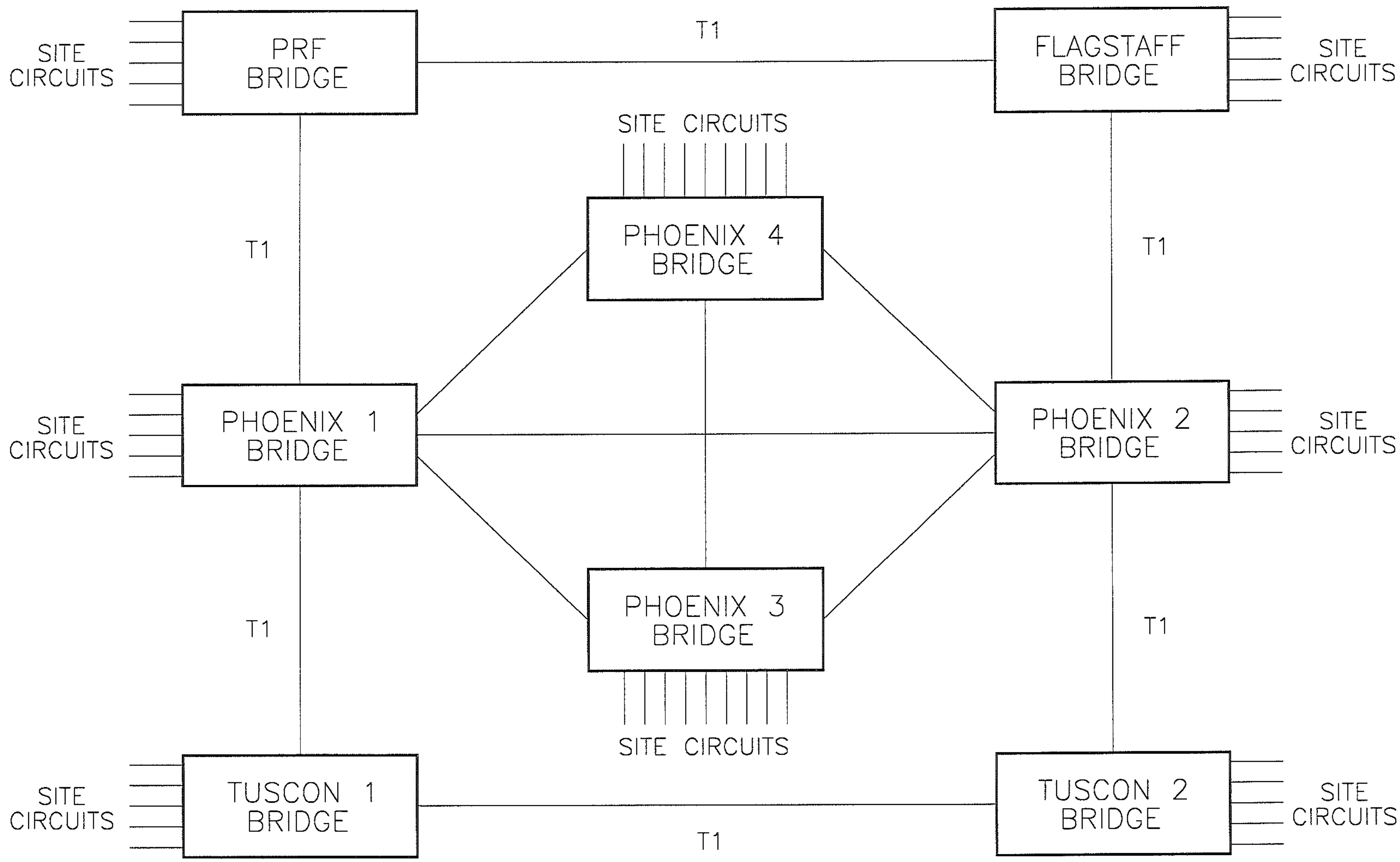
The first is a VHF Low Band Motor Vehicle Division (MVD) system consisting of:

- 14 Mountain top simplex base stations.
- Microwave interconnect from the base stations to MVD digital offices in Phoenix and Tucson.
- 15 Local base stations.
- 125 Mbile radios.

The system is approximately 15 years old. It does not use repeaters and is subject to cyclical skip interference. (**Figure 5.2-1** is a block diagram of the system.) MVD has plans to replace this system with a VHF high band system using a federal grant.

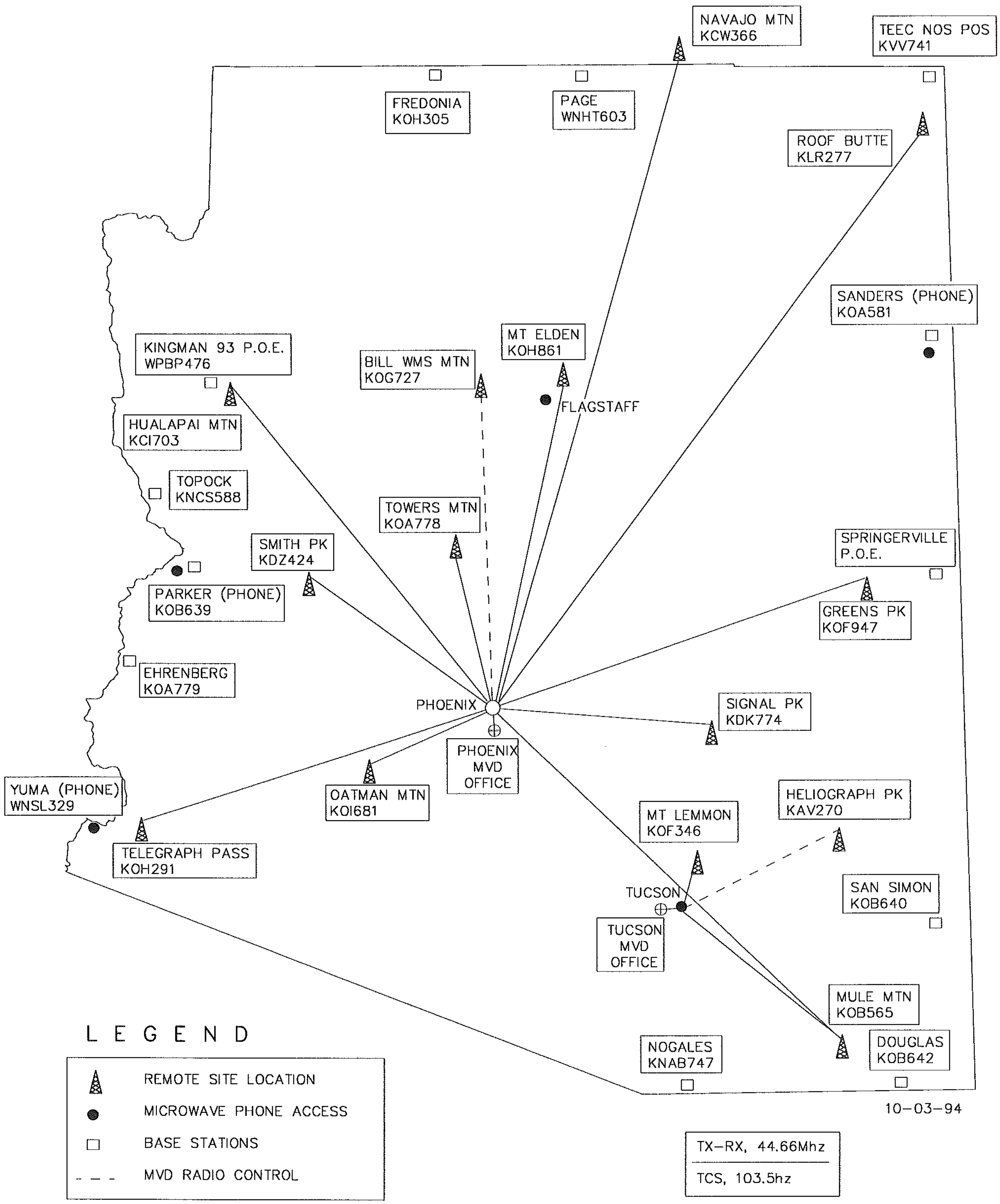
The second system is a statewide VHF High Band repeater network. This system consists of:

- 37 Repeaters, or 35 mountaintop sites, linked over the DPS analog microwave system.



ADOT WAN Network Summary Block Diagram

(Backbone Only)
Figure 5.1–1



MVD VHF Low Band Radio System

Figure 5.2-1

- Connections to district dispatch centers (except Phoenix) via ADOT/DPS microwave and wireline.
- VHF repeaters controlled by the FMS TOC in Phoenix via a digital microwave link to South Mountain.
- 1535 Mobile radios.
- 319 Portable radios.
- 149 Base stations.

The equipment is 10 to 15 years old and is being modified to a new ADOT maintenance district configuration. **Figure 5.2-2** is a block diagram of the systems.

The third system is an 8-channel, 800 MHz trunked simulcast system on three mountaintop sites in Maricopa County, as depicted in **Figure 5.2-3**. It uses ADOT's 10 GHz digital microwave system to link sites. Fifteen (15) talk groups are set up for District 1 construction and maintenance operations; four (4) talk groups are set up for MVD operations in Phoenix. The equipment includes:

- 24 Mountaintop base/mobile relay stations.
- 31 Base stations on 800 MHz.
- 438 Mobile radios.
- 112 Portable radios.

This system is three years old.

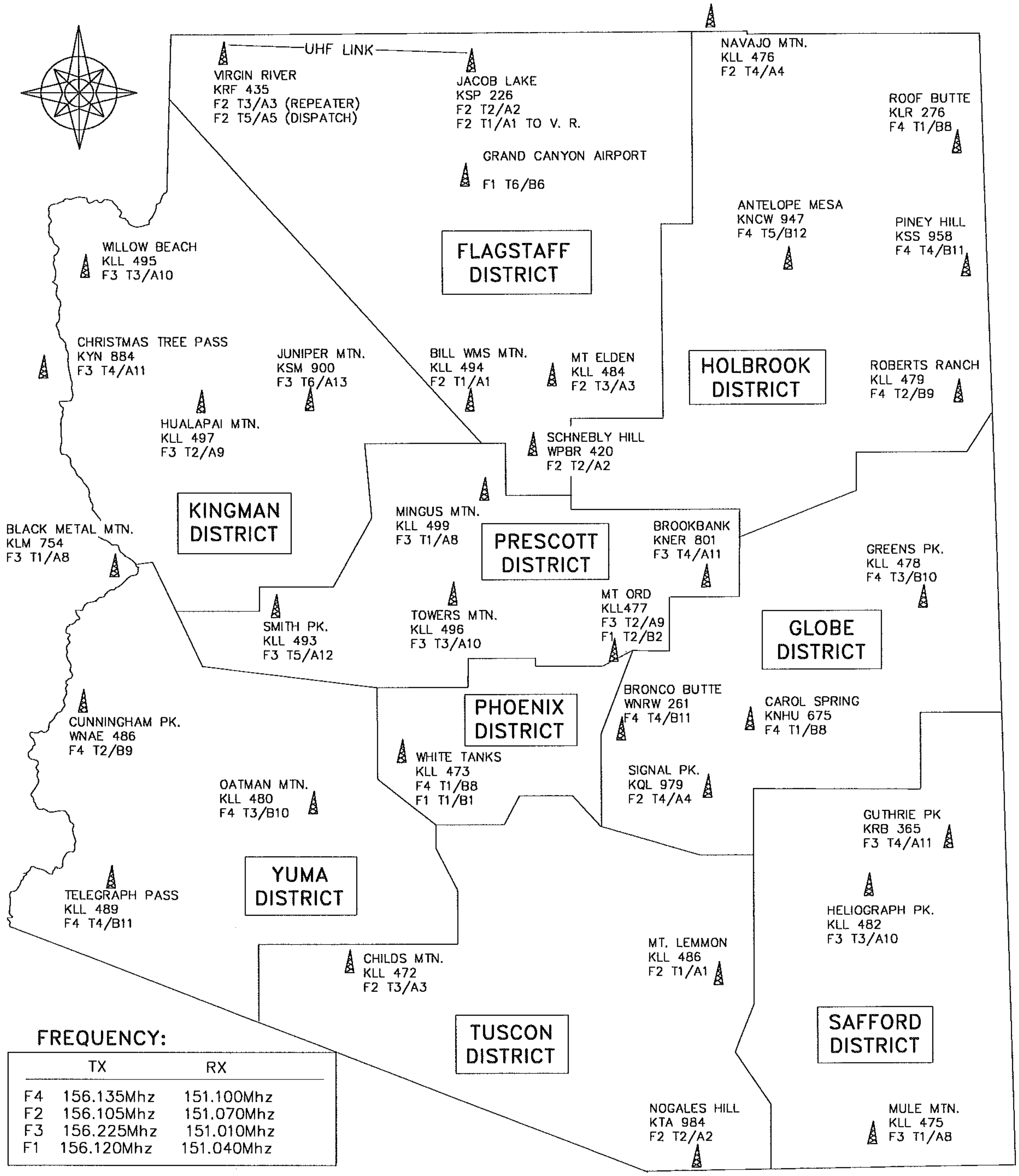
DPS operates several radio systems:

- Old statewide VHF channel maintained for outside agency interoperability.

- The Highway Patrol system on UHF 450/460 MHz consisting of 6-channel pairs reused over 11 districts, with 115 stations on 48 sites, plus a statewide channel.

- Criminal Investigation operates a two (2) channel UHF system consisting of 21 stations at 17 sites statewide.

- The Telecommunications Division operates a UHF radio system used strictly for maintenance of the statewide microwave/radio network. It consists of 16 stations on 16 sites. An obsolete VHF "State" radio system still exists on 12 sites.



FREQUENCY:

	TX	RX
F4	156.135Mhz	151.100Mhz
F2	156.105Mhz	151.070Mhz
F3	156.225Mhz	151.010Mhz
F1	156.120Mhz	151.040Mhz

PL TONE:

T1 136.5Hz RX			
T2 127.3Hz RX		T5	146.2Hz RX
T3 118.8Hz RX		T6	156.7Hz RX
T4 110.9Hz RX		T7	103.5Hz RX

(A,B, 1–16)
MOBILE CHANNEL SELECT

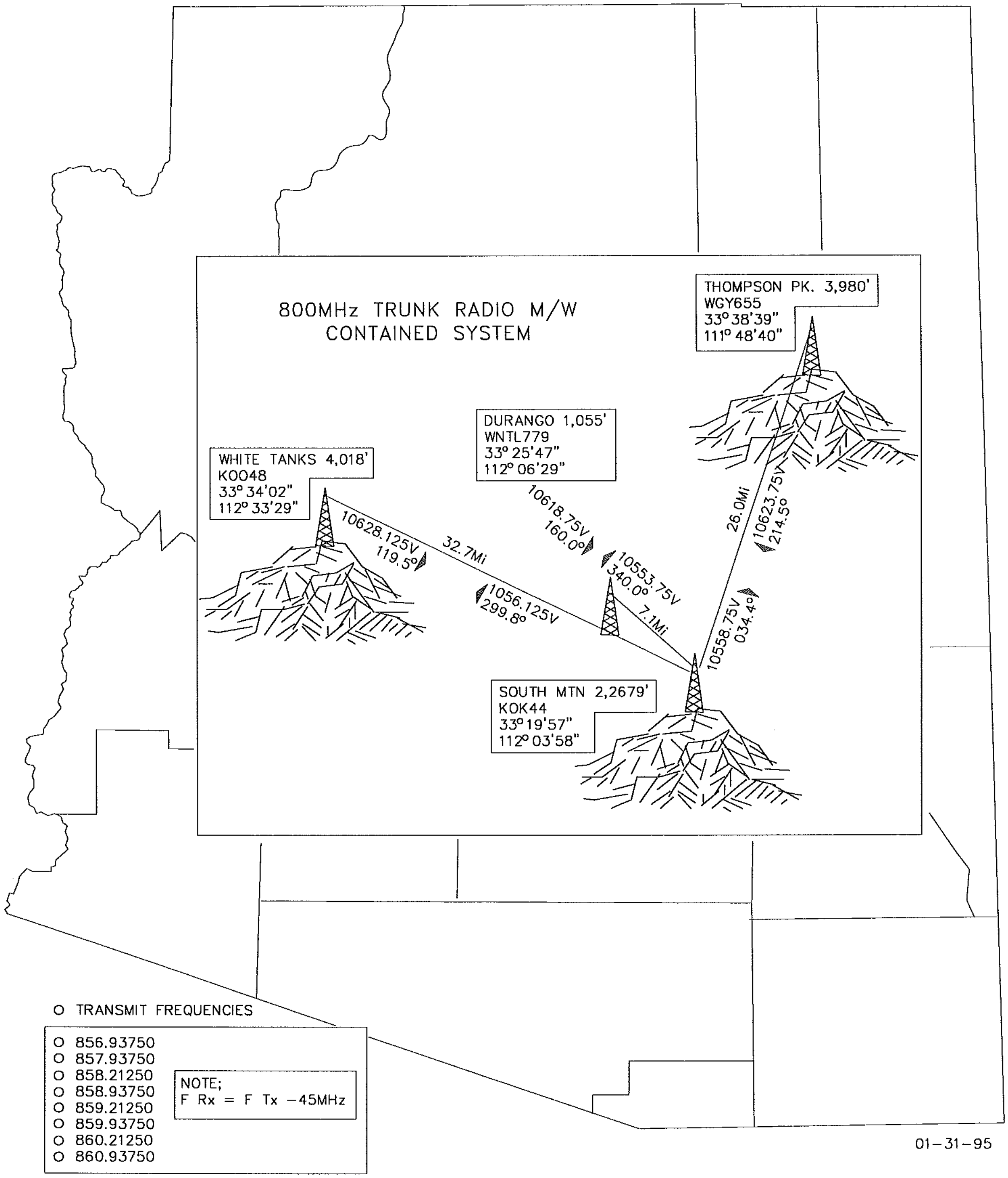
06–15–95

NOTES:

- ☐ 1. BASE TRANSMITS HIGH FREQUENCY
- ☐ 2. MOBILE TRANSMITS LOW FREQUENCY
- ☐ 3. MOBILE SUB-AUDIBLE RECEIVE TONE FREQUENCY. 103.5 ALL CHANNELS

ADOT Radio System

Figure 5.2–2



ADOT 8-Channel Trunked Simulcast System

(MARICOPA COUNTY)

Figure 5.2-3

Other equipment consists of:

- Approximately 1500 mobile radios.
- 1250 Portable radios.
- Dispatch centers in Phoenix, Tucson, and Flagstaff.

None of the channels used by DPS are directly compatible with any ADOT radio system. Interconnection is possible only at dispatch centers through cross scanning or cross patching.

In response to the FCC's Refarming Report and Order (R&O), issued on June 15, 1995, DPS indicates that plans will be developed to upgrade these systems; however, the R&O does not require upgrades to the VHF low and 800 MHz bands.

5.3 PHOENIX FMS COMMUNICATION SUBSYSTEM

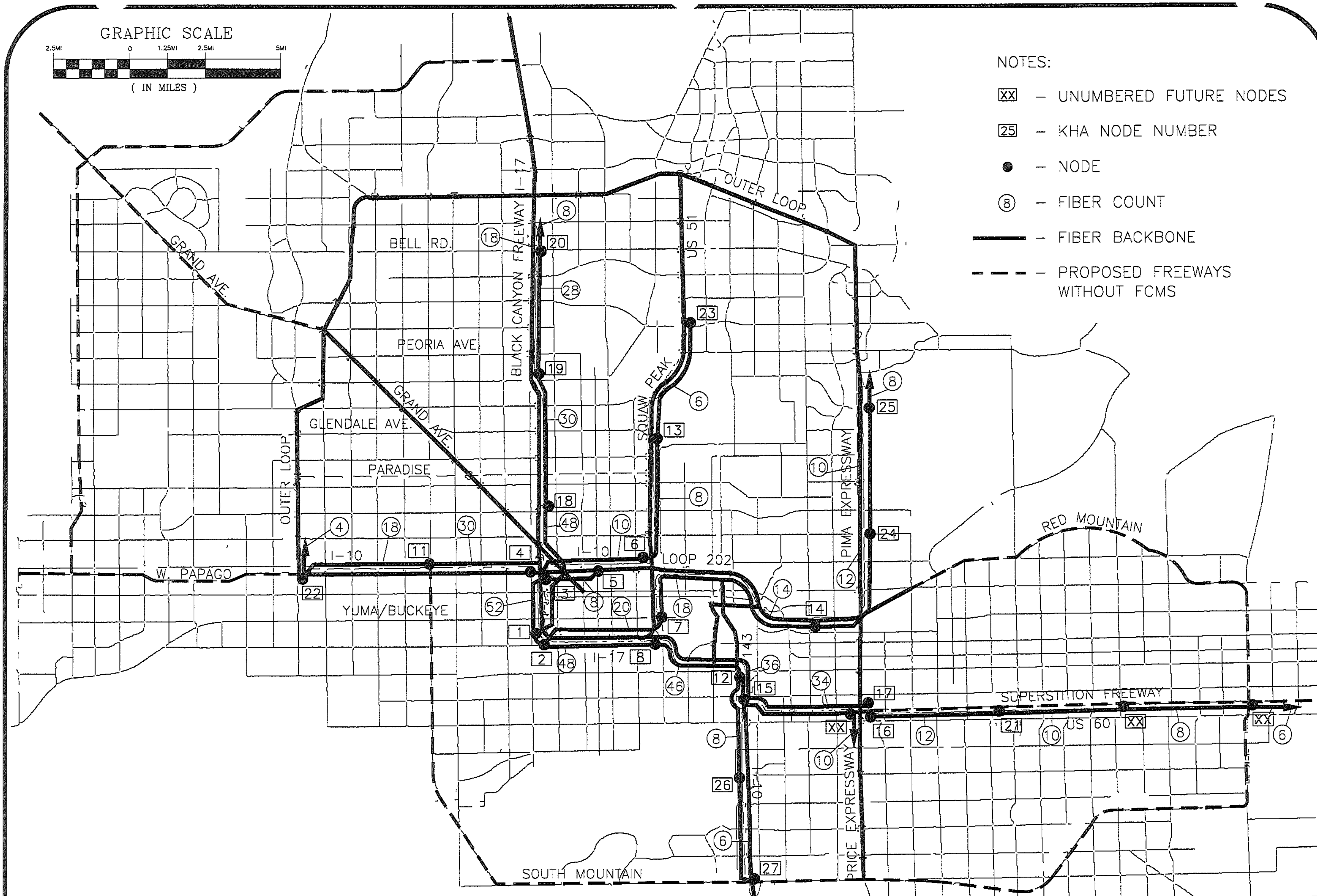
The Phoenix FMS has plans to instrument and equip over 200 miles of freeway in the Maricopa County/Phoenix area as depicted in **Figure 5.3-1**. This figure also depicts the current approximately 29 miles of instrumented and equipped freeway predominantly along I-10 and I-17. **Figure 5.3-2** illustrates how field equipment is connected to the TOC via the communications subsystem. In summary, the communications subsystem consists of:

- An SMFO fiber backbone from TOC to communications nodes located approximately every 5 miles.

- An overlay of fiber and twisted wire pair (TWP) local links from communications nodes to field equipment controller cabinets. The fiber links are for CCTV cameras located at approximately 1-mile intervals. The TWP links are for low-speed controller data using multidrop, 1200/2400 bps series 400 modems.

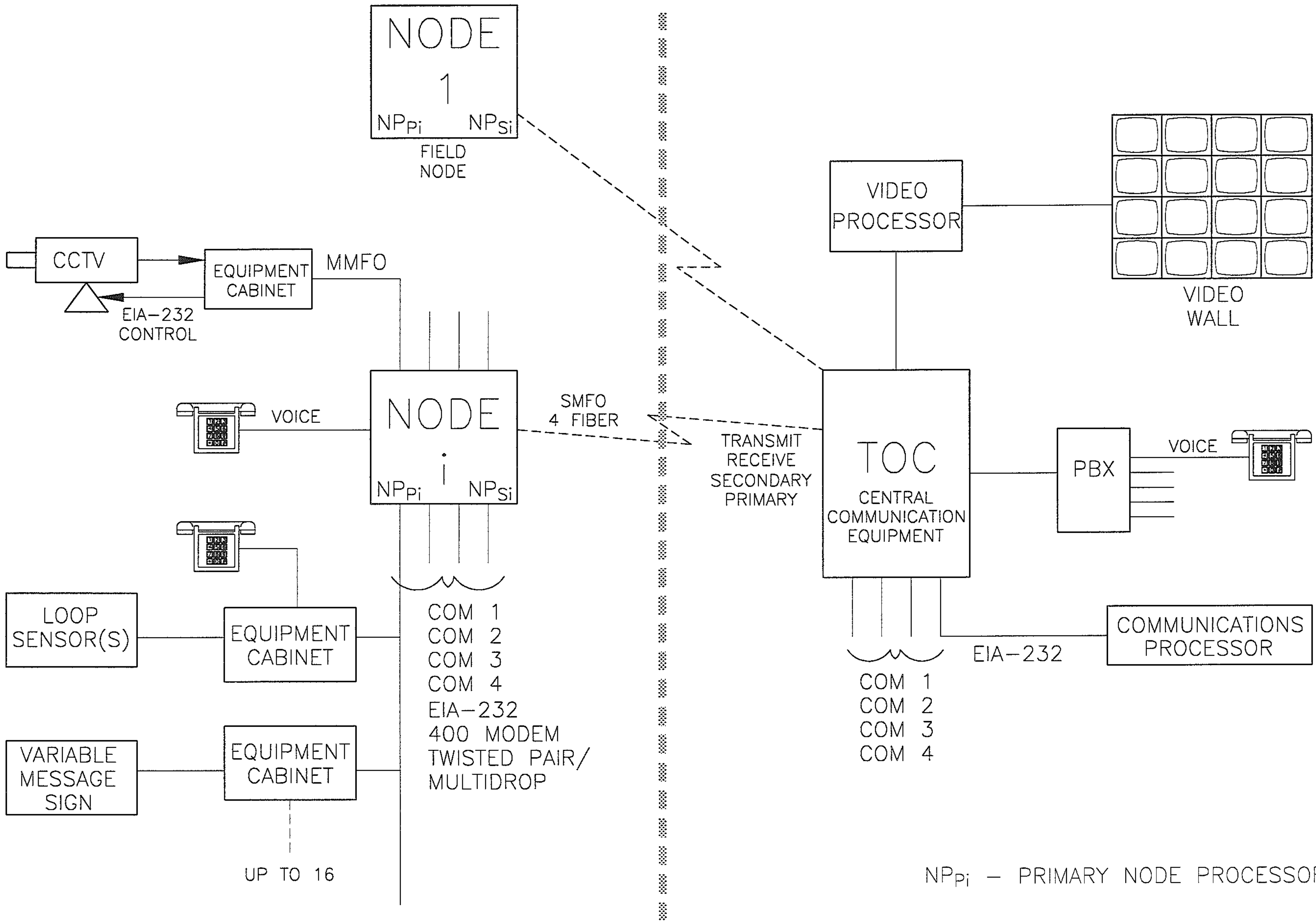
- The video and data are Frequency Division Multiplexed (FDM) at the communications nodes for communications to/from the TOC.

The FDM multiplexing is a proprietary technique that was typical of designs and products in the 1988-1992 time period of FMS design. Now, however, ITS is transitioning to open, non-proprietary standard designs. Fortunately, the expensive SMFO cable plant ***is*** suitable for the emerging open, standard designs.



FMS Communication System
29 Miles Implemented, Over 200 Miles Planned

Figure 5.3–1



NP_{Pi} – PRIMARY NODE PROCESSOR

NP_{Si} – SECONDARY NODE PROCESSOR

Communication Subsystem Connection

Figure 5.3-2

5.4 COMMERCIAL SERVICES

There are many commercial service providers in the state of Arizona. In **Appendix A**, we have provided lists of:

- Cellular Service Providers.
- Commercial Telephone Service Providers.

5.4.1 ISDN

Integrated Services Digital Network (ISDN) is a digital dialup telephone service that was conceived to provide end-to-end digital telephone service. After years of hype and unrealized potential, ISDN appears to have achieved some recent successes largely as a result of demand for higher speed (compared to dialup modem) access to internet services. It is also widely used by the radio broadcast industry for higher quality voice transmission from remote sites (e.g., sports arena, etc.) and will offer similar benefits to ITS.

For years, the commercial telephone network has employed digital switching, multiplexing (i.e., T1 digital hierarchy), and transmission. However, the TWP connecting the Central Office (CO) switch to subscriber telephones has been analog as depicted in the lower part of **Figure 5.4.1-1**. ISDN essentially extends the digital DS-0 (or B channel in ISDN terminology) to the subscriber premise as depicted in the upper part of **Figure 5.4.1-1**.

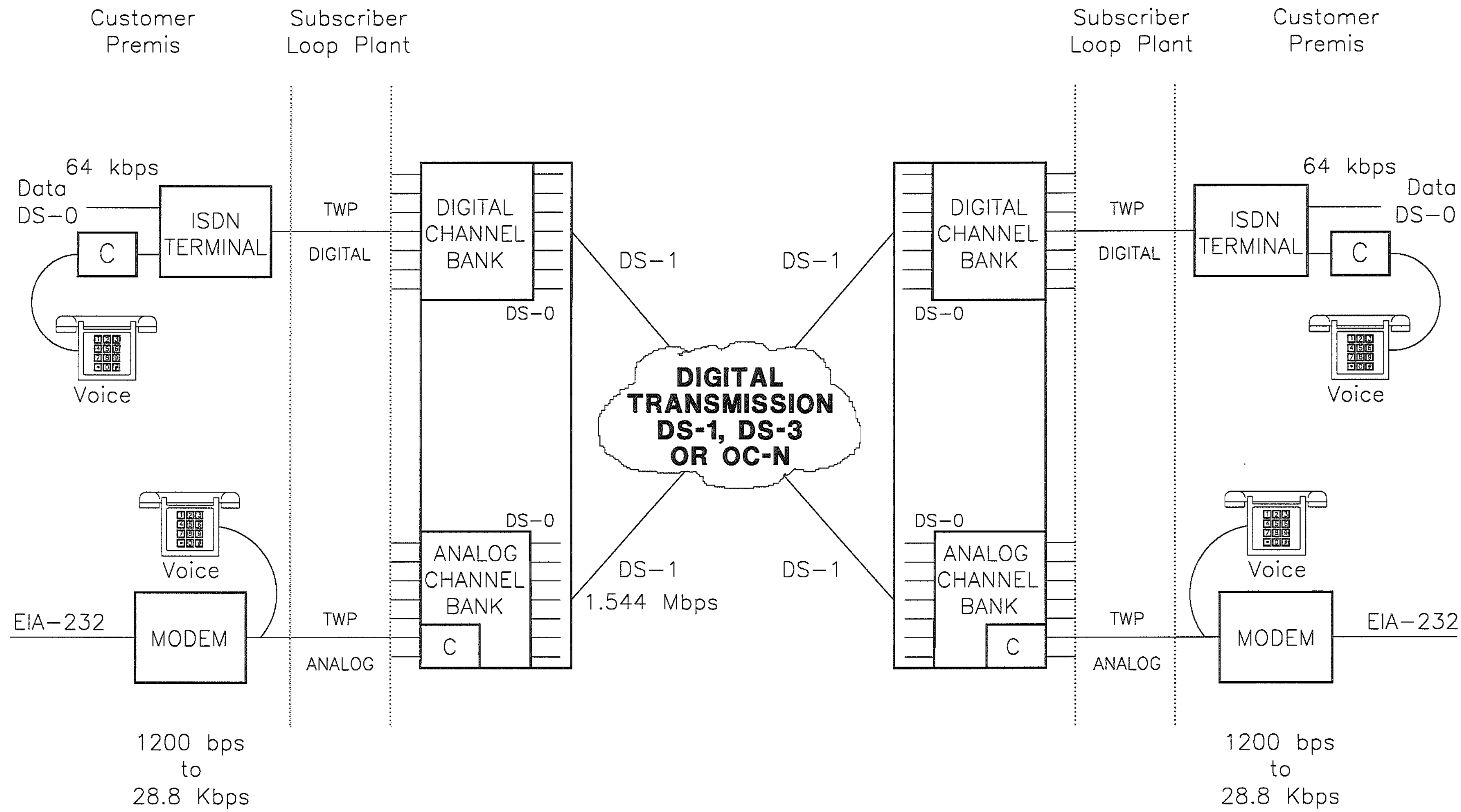
A D (or data) channel is also provided to serve the equivalent telephone signal/control functions such as on/off hook, DTMF dial tones, busy signal, etc., tones that are provided "in-band" on the standard analog telephone circuits. Additionally, this D channel may also serve as a packet data channel for packet services, although most current services appear to use B channels.

ISDN is basically a WAN service that is available in two forms:

- Basic Rate Interface (BRI).
- Primary Rate Interface (PRI).

BRI provides the following:

- 2 B Channels (DS-0, 64 kbps) for a total of 128 kbps.
- 1 D Channel at 16 kbps.
- Deployment over existing telephone company TWP loop plant by providing ISDN terminals at both the customer premises and the service CO (see **Figure 5.4.1-1**).



C – CODEC (ie, analog-digital conversion)

ISDN: End-to-End Digital Connectivity

Figure 5.4.1-1

PRI provides:

- Essentially DS-1 service at 1.544 Mbps.
- Up to 23 DS-0 channels available within the DS-1 frame, (although other rates can be supported).
- 1 D channel at the DS-0 rate of 64 kbps.
- This requires special 4-wire TWP circuits and repeaters for longer distances (the equivalent of T1 DS-1 circuit requirements).

Costs for ISDN circuits vary and can include (for BRI):

- Installation charges (0-$150).
- Per-month circuit charges ($20-$60).
- Per-minute usage charges (0 to $0.19 per minute).

Appendix A contains a list of U.S. West's Arizona ISDN BRI single line service availability by wire center.

6.0 RECOMMENDED ITS COMMUNICATION STRATEGY

The ITS goal of integrated transportation services requires an evolution to open architectures and standards. In fortunate support, the communication industry is converging toward standards based on hierarchial multiplexed data rate capabilities:

- Multiplexed EIA-232/422/485/503 and related interfaces (below 64 kbps).
- Subrate multiplexing (64 kbps and below).
- The digital hierarchy (i.e., DS-0, DS-1, DS-3, etc.).
- The SONET standards (i.e., OC-1, OC-3, etc; above 51.84 Mbps).

The concept is illustrated in **Figure 6.0-1**.

These standards provide a well conceived and tested framework for communicating data by multiplexing for transmission and switching, routing, or bridging at nodes equipped to provide delivery from source to destination. The key capability is to identify cost effective opportunities for multiplexing using techniques and equipment deployed for years in the LAN/WAN and telecommunication industries.

The hierarchy has data rates from the traditional 1200 bps deployable over TWP up to 10 Gbps at SONET OC-192 rate that practically only fiber will support. ITS has unique characteristics that require flexibility. These include:

- A multitude of services as described in 2.1 that will have evolutionary deployment.

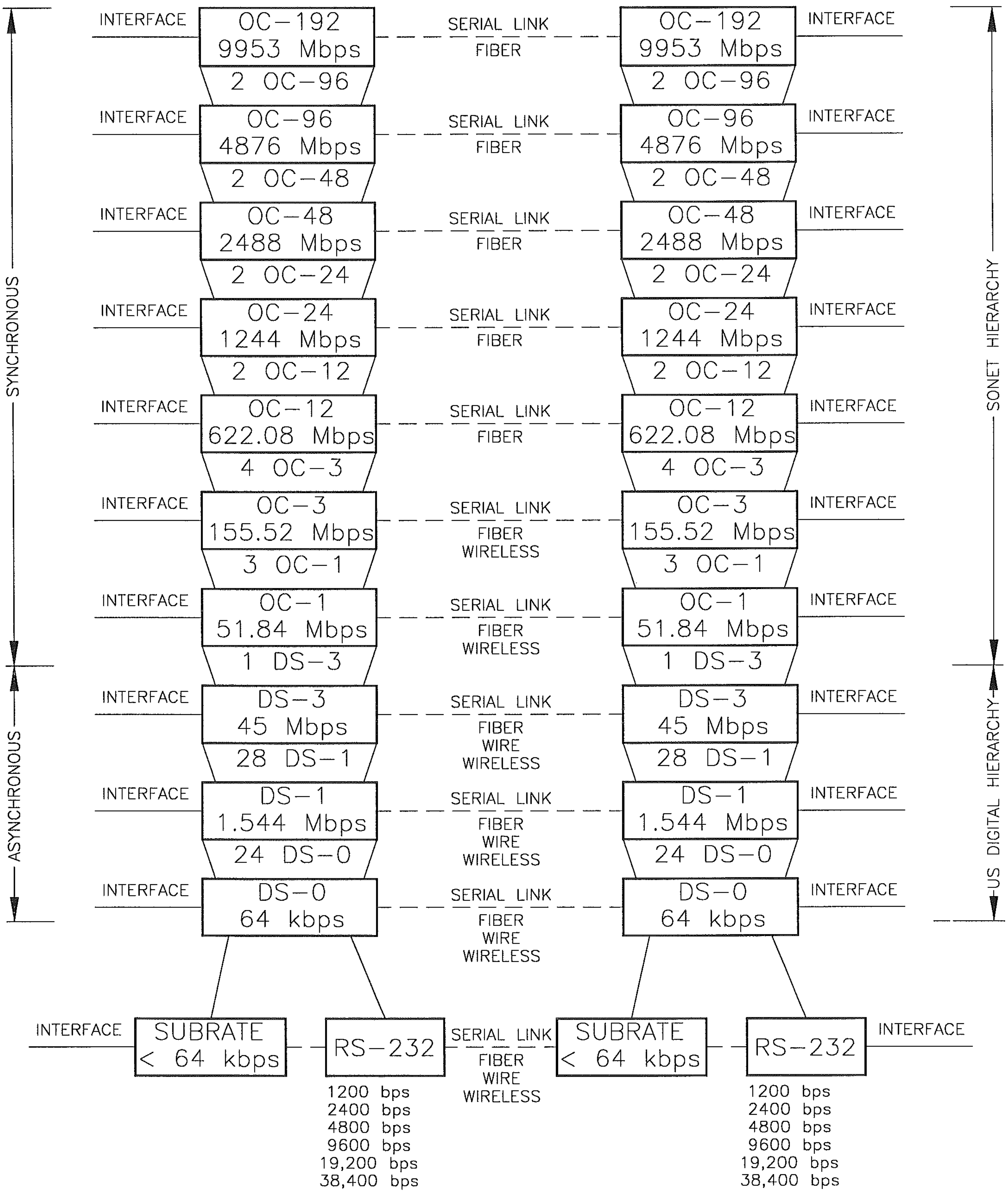
- Local agency/jurisdictional operational requirements that are unique in terms of services deployed and exact service feature sets.

- A growing complement of field sensor/equipment types that include the traditional signal systems (loops), VMS, ramp meters, weather, HAR, etc. Each has unique message sets to support unique data content.

- Diverse geographical areas ranging from sparse rural areas to dense urban areas.

- Need for multimodal operations and shared data. Often multiple TOCs are required at multiple jurisdiction locations, often with emergency and after-hour capabilities.

- Legacy ITS-related system that must be integrated.



Standards-based Digital Multiplexed Data Rate Hierarchy

Figure 6.0-1

No single communication architecture, topology, and/or media can cost-effectively serve all requirements. Thus, flexible architectures are required which the Standards-based multiplexed architecture and interfaces depicted in **Figure 6.0-1** provide. Communication systems are designed to standard interfaces (see **Figure 6.0-2**) and contain only the higher levels as necessary to cost-effectively support the composite multiplexed system data rates as geographically distributed. Since industry standard interfaces are employed, private networks and/or commercial communication networks can be employed based on cost or other factors.

6.1 DIGITAL HIERARCHY AND DIGITIZED VOICE

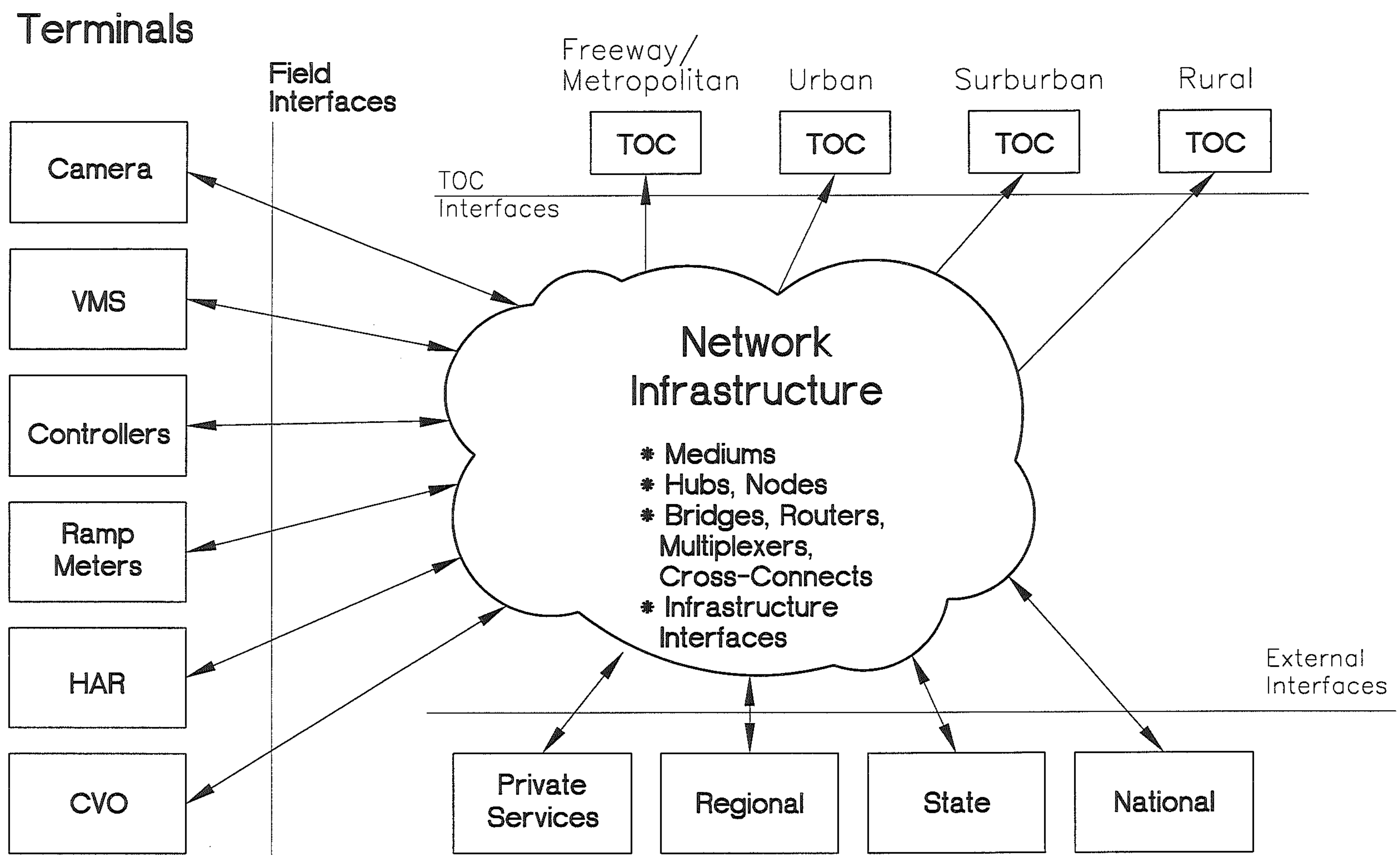
The origins of the Digital Hierarchy, or T-Carrier Systems (or T1), were the result in New York City (NYC) of subscriber growth to the extent that analog Twisted Wire Pair (TWP) required for a single analog voice was growing beyond the capacity of existing and expandable conduit space for new installations. As a solution, early implementations of the digital hierarchy were conceived that digitized up to 24 analog voice signals into 24 digital voice signals at 8 bits/sample and 8,000 samples/sec to create a DS-0 digital signal at 64,000 bps. The analog voice signal is filtered to limit the bandwidth to less than 3100-3500 Hz. These 24 DS-0 digital voice signals are then Time Division Multiplexed (TDM) into a 1.544 Mbps digital signal. The concept is illustrated in **Figure 6.1-1**. This TDM was found to be cheaper than popular alternative Frequency Division Multiplexing (FDM) alternatives of the 1950s era.

Thus, the 24 TWP for analog signals could be reduced to 2 TWP (full duplex, one for each direction). The equipment that interfaces to analog voice TWP is a channel bank and usually includes the standard telephone BORSCHT functions:

Battery (normally 48 Vdc)
Overvoltage Protection (lightning, etc.)
Ringing (Voltage)
Supervision (i.e. Dial Tone, On/Off Hook Detection, etc.)
Coding (A/D, D/A Analog/Digital Conversions)
Hybrid (i.e., 2 wire to 4 wire for full duplex)
Test

There are several alternative channel bank options that can be selected depending on the application.

The multiplexed digital signal consists of 24 DS-0 digital signals at 64 kbps and one frame bit for a total of 1.544 Mbps. This signal can be transmitted on TWP using 16 to 26 gauge cable to support repeaterless distances of 6000 feet, the common telephone industry manhole spacing. Greater TWP repeater spacing distance and data rates are supportable with careful system design including cable plant design.

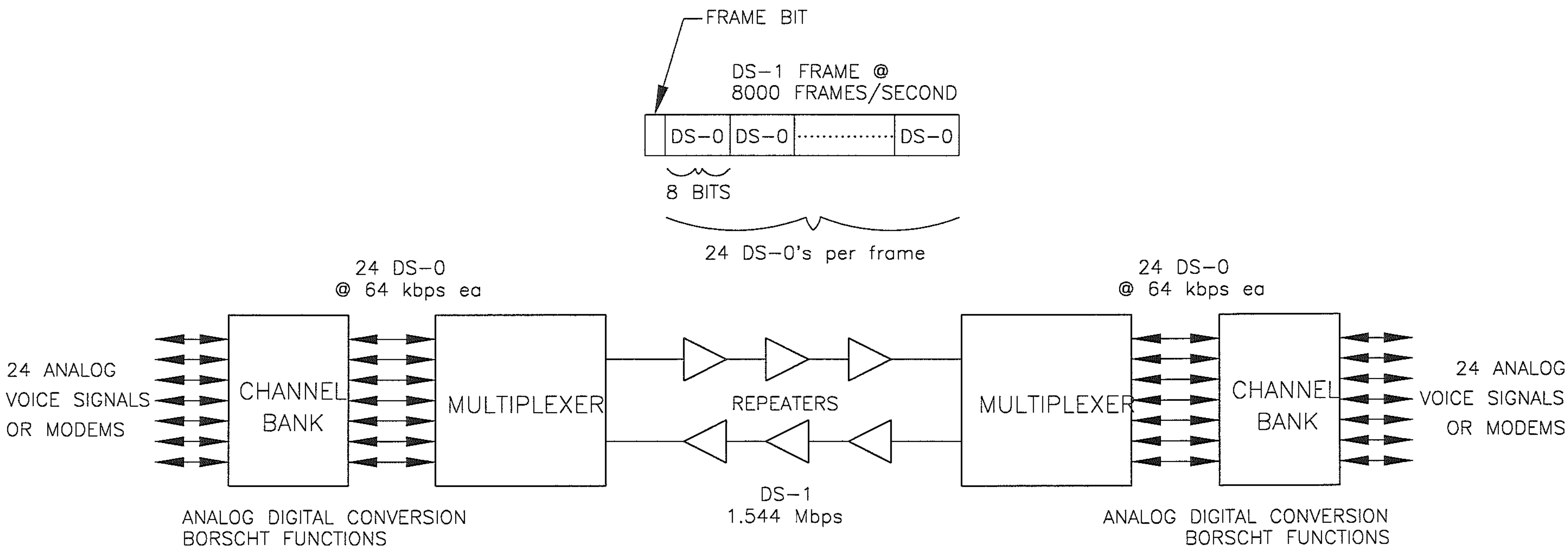


Common Communication Infrastructure

* Share Data
* TOC Backup
* Shared External Interfaces
* Reduce Communication Network Cost

ITS Standard Interfaces Communication Architecture Vision

Figure 6.0–2



DS-1 Time Division Multiplexed (TDM) Signal

Figure 6.1–1

The DS-1 (often incorrectly used synonymously as T1) was very successful and has expanded into the Digital TDM Hierarchy presented in **Figure 6.1-2** to accommodate greater multiplexing and higher data rates. The figure includes:

- The composite serial bit rate.
- Defined standard multiplexing between the various digital signal levels.
- The number of 64 kbps DS-0 (64 kbps) channels multiplexed at each digital signal level.
- The typical transmission media.

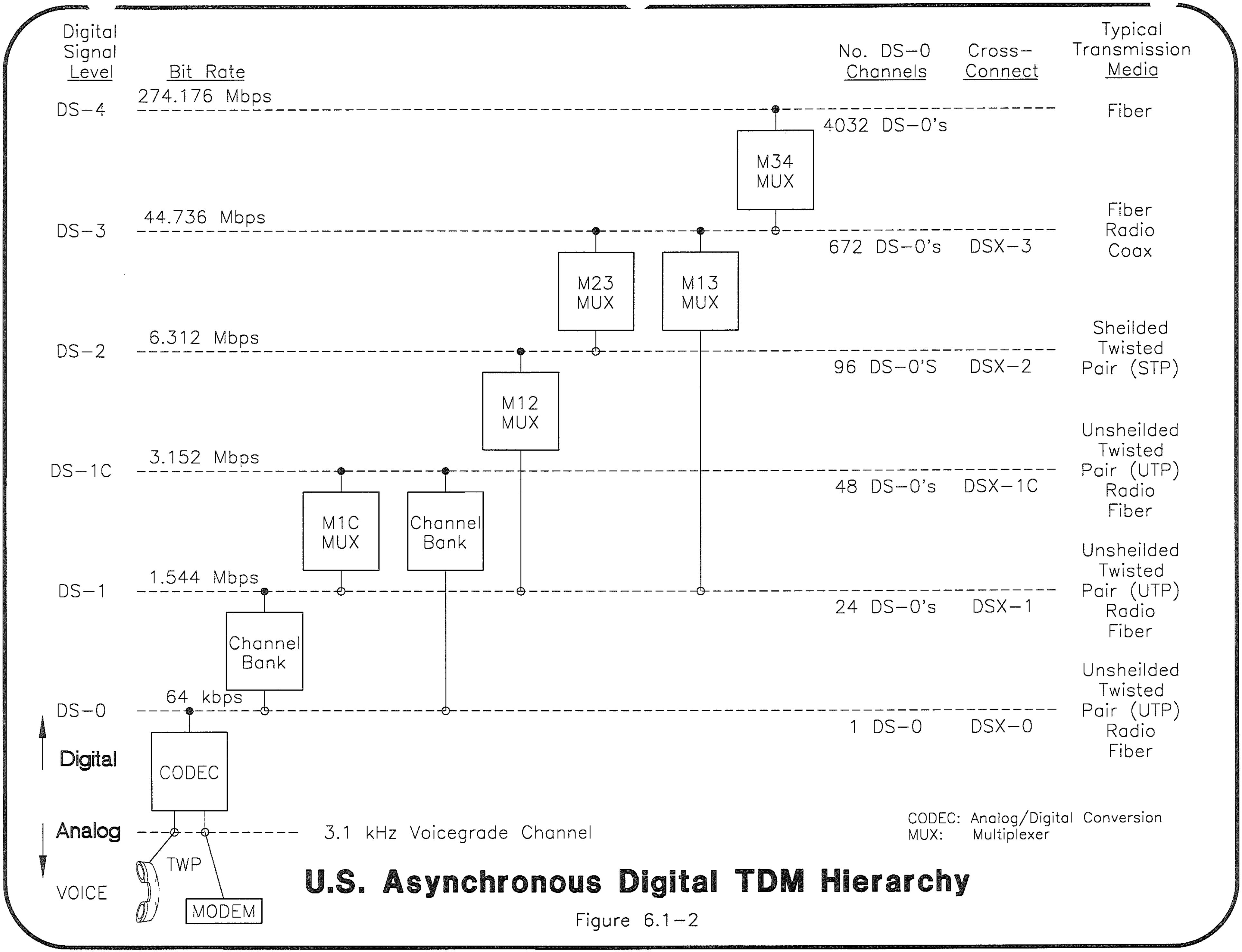
As the cost of electronics decreased, the telephone industry developed cost-effective digital Central office (CO) switches so that most calls (local and L.D.) are maintained in digital form from the CO of the calling subscriber through all intermediate transmission, multiplexing, and switching facilities to the CO of the called subscriber. The concept is illustrated in **Figure 6.1-3**. Except for PBX requirements, a switching capability or CO is usually not required for ITS and other private network infrastructure requirements; however, the transmission, multiplexing, and cross-connect equipment provides excellent capabilities. Of significance to ITS applications is the availability of high volume cost- effective, equipment for ITS communications infrastructure development.

The cross-connect depicted in **Figure 6.1-3** is an important element of modern networks. A cross-connect historically has been an electromechanical panel of jacks, plugs, and jumpers for the purpose of reconfiguring DS-0, DS-1, DS-1C, and DS-2 connections. With these panels and jumpers, the following useful system manual functions can be performed:

- Restoration of a failed circuit by using a spare.
- Rerouting for systems reconfiguration.
- Looping for testing during installation and maintenance.

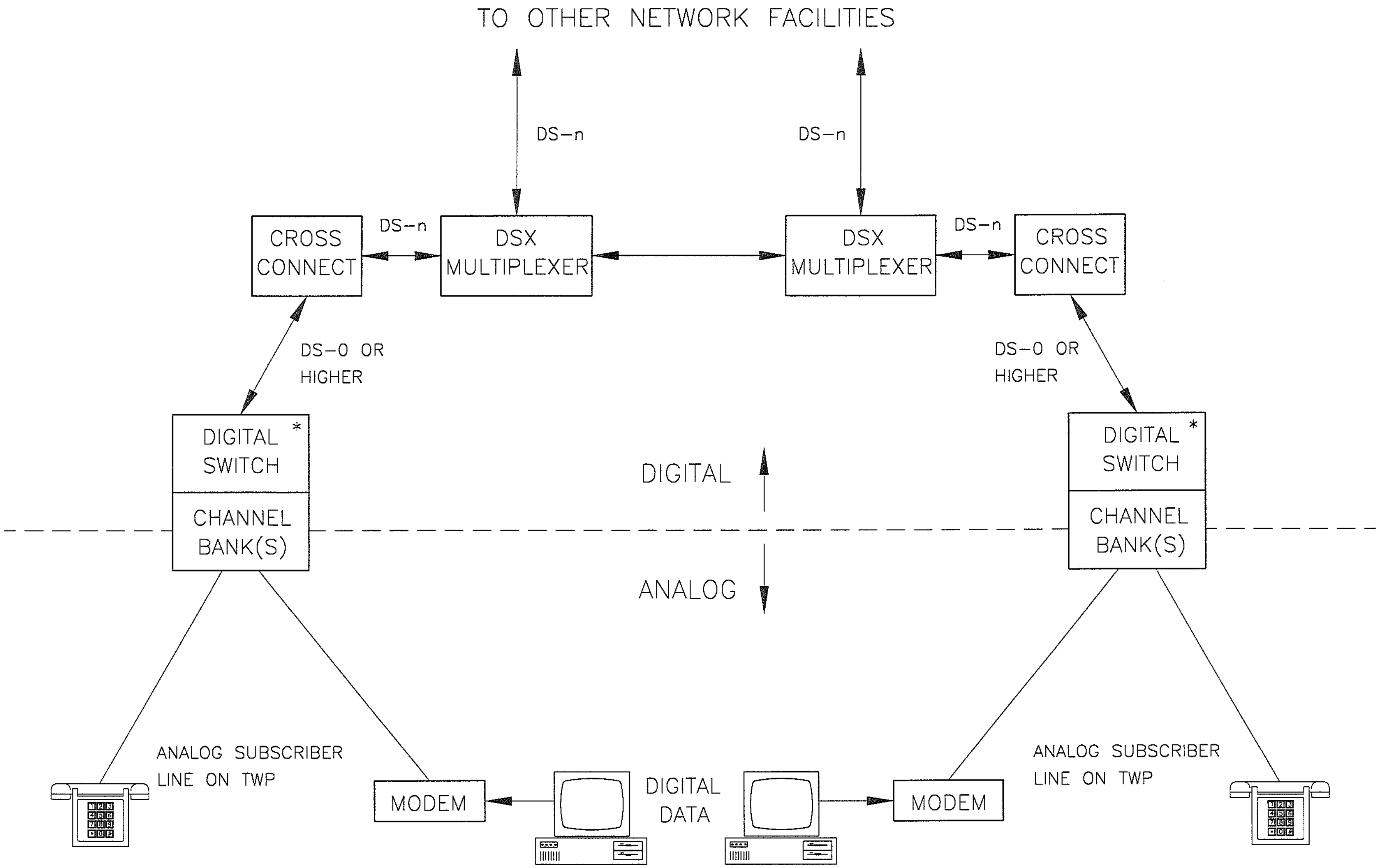
More recently, electronic cross-connects have been developed that operate at rates up to DS-3 and add significant advantage to digital transmission systems and networks by performing some of the following functions:

- Speed rearrangement of digital channels and circuits.
- Hubbing, grooming, and consolidation of channels and circuits.
- Fast rerouting of circuit, based on routine time-of-day, or temporary requirements.
- Restore failed circuits quickly by rerouting if necessary.



U.S. Asynchronous Digital TDM Hierarchy

Figure 6.1–2



* Private Networks often do not employ digital switches

Digital Telephone Network

Figure 6.1–3

- Increased flexibility by rapid electronic control.
- Network management and centralized testing; integrated network management.

Electronics cross-connects are referred to as digital access and cross-connect systems (DACS). Thus, the electromechanical DSX designators in **Figure 6.1-2** become DCS.

6.1.1 Subrate Multiplexing

The digital hierarchy provides standards for bit rates from 64 kbps (DS-0) to 274.176 Mbps (DS-4). ITS has applications for bit rates below the DS-1 and DS-0 circuits. These are addressed by T1 subrates to DS-1 or DS-0 as depicted in **Figure 6.1.1-1** with common rates. Standards exist for subrate multiplexing, but are not as widely and consistently embraced by industry. Many non-standard, often proprietary, implementations are deployed.

Of particular importance to ITS are the EIA-232 bit rates that are multiplexed in a DS-0 frame. The bit rates supported are:

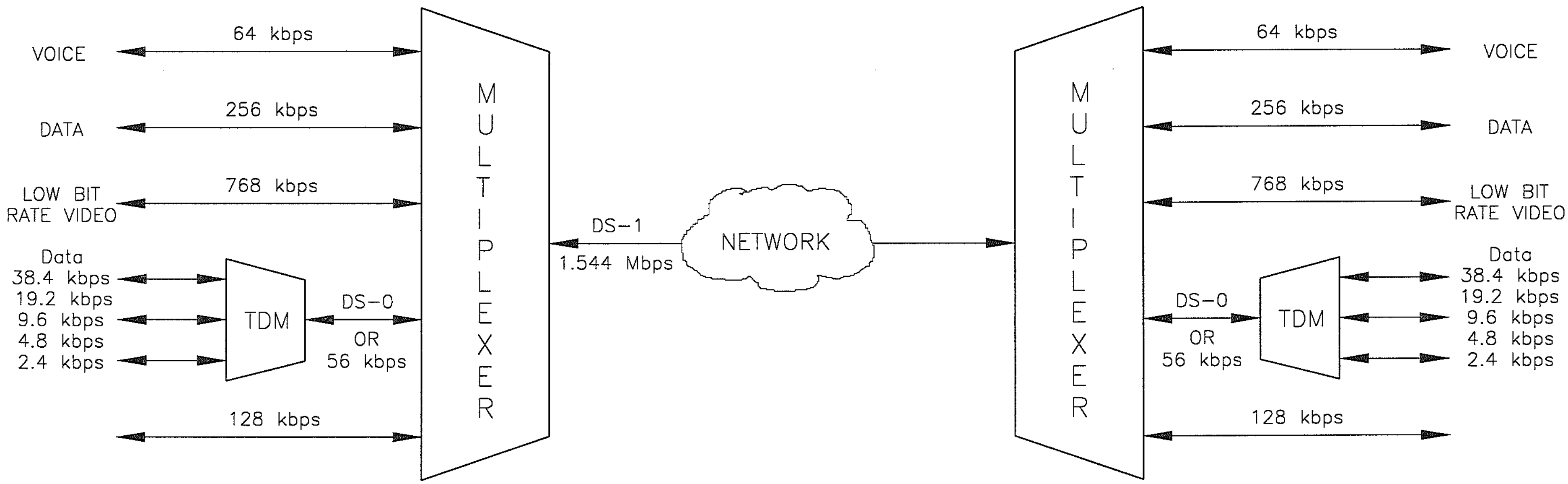
- 2.4 kbps.
- 4.8 kbps.
- 9.6 kbps.
- 19.2 kbps.
- 28.8 kbps.
- 38.4 kbps.

Commercial services are available from telephone companies that support these DS-0 subrates, typically under the name of digital data service (DDS) or subrate digital loop (SDRL).

It should be noted that 56 kbps is a common available bit rate compared to the standard 64 kbps, DS-0 bit rate. This lower rate is actually a DS-0 frame, but with a "robbed bit" used for traditional signal functions (off/on hook status). The bit rate (BR) is:

Bit Rate = 7 bits/sample x 8,000 samples/sec = 56 kbps

Many commercial services are available at 56 kbps, although the modern trend is a full "clear" 64 kbps, DS-0 channel.



Subrate Multiplexing

Figure 6.1.1-1

6.1.2 Digital Hierarchy Standards

The complete list of standards for T1, Digital Hierarchy would be long. Below is an abbreviated list covering important topics. Expanded references are included.

The U.S. T1 digital hierarchy standards include:

American National Standard for Telecommunications. *Digital Hierarchy — Formats Specifications.* ANSI T1.107-1988.

Access Specification for High Capacity (DS1/DS3) Dedicated Digital Services. AT&T Technical Reference TR62415, June 1989. Available from AT&T Corporate Mailings.

High Capacity Digital Service (1.544 Mb/s) Interface Generic Requirements for End Users. BELLCORE Technical Reference TR-NPL-000054, April 1989. Available from BELLCORE Customer Service.

Digroup Terminal and Digital Interface Frame Technical Reference and Compatibility Specification. AT&T Compatibility Bulletin 123, Aug. 1981. Available from AT&T Corporate Mailings.

Digital Channel Bank Requirements and Objectives. Bell System Transmission Engineering, BELLCORE Technical Reference TR43801, Nov. 1982. Available from BELLCORE Customer Service.

American National Standard for Telecommunications. *Carrier-to-Customer Installation, DS1 Metallic Interface.* ANSI T1.403-1989.

Requirements for Interfacing Digital Terminal Equipment to Services Employing the Extended Superframe Format. AT&T Technical Reference TR54016, Sept. 1989. Available from AT&T Corporate Mailings.

Data Communication Networks: Services and Facilities Interfaces. Recommendations X.1-X.32. CCITT Blue Book, Vol. VIII, Fascicle VIII.2, Geneva, 1989. Available from NTIS.

General Aspects of Digital Transmission Systems; Terminal Equipments. Recommendations G.700-G.772. CCITT Blue Book, Vol. III, Fascicle III.4, Geneva, 1989.

Integrated Digital Loop Carrier System Generic Requirements, Objectives, and Interface. BELLCORE Technical Reference TR-TSY-000303, Sept. 1986, revision 4, Aug. 1991.

American National Standard for Telecommunications. *Integrated Services Digital Network (ISDN): Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT (Layer 1 Specification).* ANSI T1.601-1988.

Digital Networks, Digital Sections and Digital Line Systems. CCITT Blue Book, vol. III, Fascicle III.5, Geneva, 1989. Available from NTIS, Order No. PB89-143895.

American National Standard for Telecommunications. *Digital Hierarchy: Supplement to Formats Specifications (Synchronous Digital Data Format).* ANSI T1.107b-1991.

Generic Requirements for High-Bit-Rate Digital Subscriber Lines. BELLCORE Technical Advisory TA-NWT-001210, oct. 1991. Available from BELLCORE Customer Service.

American national Standard for Telecommunications. *Digital Hierarchy: Electrical Interfaces.* ANSI T1.102-1987.

The subrate standards include:

Subrate Data Multiplexing, A Service Function of DATAPHONE® Digital Service. AT&T Technical Reference TR54075, Nov. 1988.

Secondary Channel in the Digital Data System: Channel Interface Requirements. BELLCORE Technical Reference TR-NPL-000157, BELLCORE, April 1986. Available from BELLCORE Customer Service.

Digital Data System Channel Interface Specifications. AT&T Technical Reference PUB 41021, March 1987. Available from AT&T Corporate Mailings.

Digital Data System Channel Interface Specification. AT&T Technical Reference PUB 62310, Nov. 1987; Addendum 1, Jan. 1988; Addendum 2, Oct. 1989; Addendum 3, Dec. 1989. Available from AT&T Corporate Mailings.

D3 and D4 Subrate Dataport Channel Unit Technical Reference and Compatibility Specification. AT&T Compatibility Bulletin No. 126, April 1981. Available from AT&T Corporate Mailings.

D3 and D4 56 KB Dataport Channel Unit Technical Reference and Compatibility Specification. AT&T Compatibility Bulletin No. 141, April 1981. Available from AT&T Corporate Mailings.

Digital Channel Banks: Requirements for Dataport Channel Unit Functions. BELLCORE Technical Advisory TA-TSY-000077, 1986. Available from BELLCORE Documents Registrar.

Generic Requirements for the Digital Data System (DDS) Network Office Channel Unit. BELLCORE Technical Advisory TA-TSY-000083, April 1986. Available from BELLCORE Documents Registrar.

Generic Requirements for the Subrate Multiplexer. BELLCORE Technical Advisory TA-TSY-000189, April 1986. Available from BELLCORE Documents Registrar.

Digital Data System (DDS) Multipoint Junction Unit (MJU) Requirements. BELLCORE Technical Advisory TA-TSY-000192, April 1986. Available from BELLCORE Documents Registrar.

A readily available reference on engineering of T1 carrier repeatered lines is:

Cravis, H., Crater, T. "Engineering of T1 Carrier System Repeatered Lines," *Bell System Technical Journal* Vol. XLII, March 1963, p. 431.

6.2 SONET

SONET (Synchronous Optical Network) technology was conceived in 1985 and a standardization process initiated in an ANSI-accredited T1 Committee to standardize commercial carrier-to-carrier optical interfaces. Single Mode Fiber Optic (SMFO) cable was emerging as the medium of choice for high-speed digital transmission systems. It should be noted that the T1 digital hierarchy does not define the physical media standards for fiber, so that many fiber-based DS-n implementations do not always facilitate off-the-shelf multivendor interoperability. The fundamental motivations for SONET emphasized the need to procure fiber-based equipment for multiple-owner systems from multiple manufacturers that will interoperate. This standard provides both a usable standard for ITS and a recent example of a successful standards process.

The SONET bit rates are presented in **Table 6.2-1** (and an abbreviated list of the more popular rates in **Figure 6.0-1**). It should be noted that SONET was originally motivated as a "mid-fiber meet" for the emerging mid-80s competitive Long Distance carriers (e.g., MCI) to the diverted Regional Bell Operating Companies (RBOCs) (e.g., U.S. West). Historically, this was predominantly accomplished using DS-3 TDM equipment. Thus, the fundamental OC-1 bit rate was selected at 51.84 Mbps which provides DS-3 payload capabilities and approximately 15% overhead primary for enhancements to better support network operations.

Additionally, SONET offers advantages over the T1 digital hierarchy:

- SONET is synchronous and can support add/drop capabilities of lower rate signals. Thus, expensive multiplexing equipment is not required to insert/extract lower rate signals at intermediate network locations. **Figures 6.2-1a** and **b** illustrate the concept. Thus, networks can be more cost-effectively implemented.

- The SONET standard provides nearly 5% of the bit rate for support of advanced network management, operations, administration, maintenance, and provising functions. This is in addition to the fundamental payload. These capabilities are not consistently defined (mostly not available) in the T1 hierarchy.

Table 6.2-1

SONET Multiplexing Hierarchy

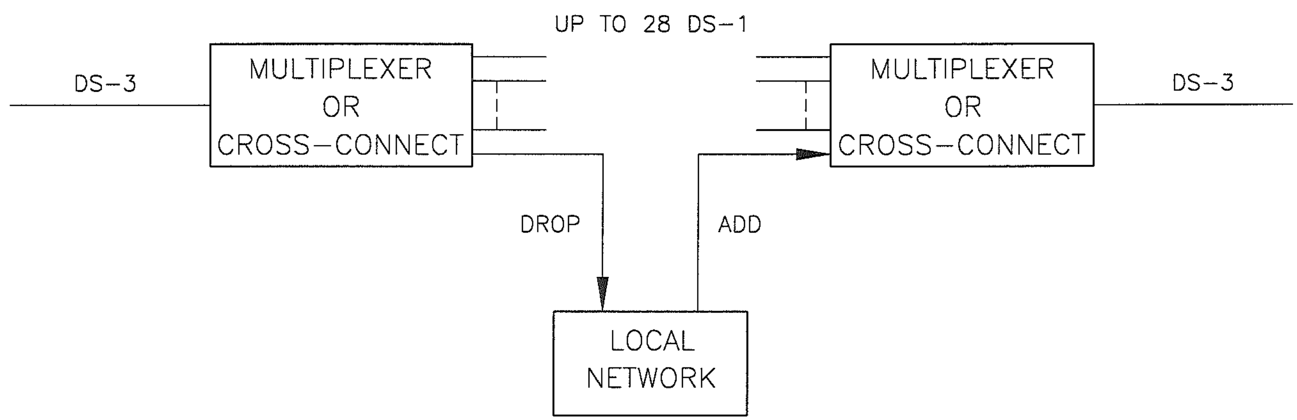
Optical/Electrical Level	Bit Rate	Number of DS-3	Number of DS-1	Number of DS-0
OC-1/STS-1	51.84 Mbps	1	28	672
OC-3/STS-3	155.52 Mbps	3	84	2,016
OC-9/STS-9	466.56 Mbps	9	252	6,048
OC-12/STS-12	622.09 Mbps	12	336	8,064
OC-18/STS-18	933.12 Mbps	18	504	12,096
OC-24/STS-24	1244.16 Mbps	24	672	16,128
OC-36/STS-36	1866.24 Mbps	36	1,008	24,192
OC-48/STS-48	2488.32 Mbps	48	1,344	32,256
OC-96/STS-96	4876.64 Mbps	96	2,688	64,512
OC-192/STS-192	9953.28 Mbps	192	5,376	129,024

- SONET was conceived as a fiber standard, OC-n*s*. Although STS-n defines electrical standards, electrical physical level transmission is not deployed. In contrast, the DS-n, T1 digital hierarchy evolved to support wire and radio and does not define optical physical transmission standards.

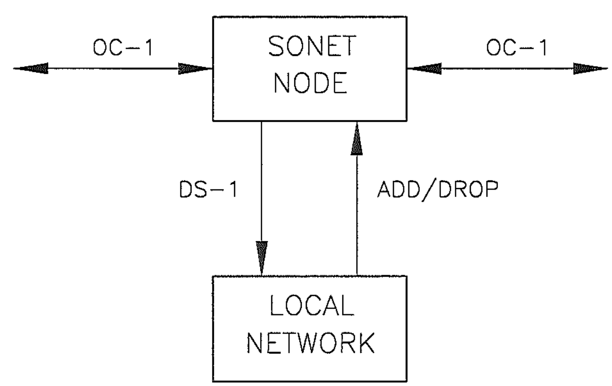
- SONET is an international standard (called Synchronous Digital Hierarchy [SDH] internationally).

- SONET can transport the legacy, widely deployed, DS-n, T1 hierarchy signals, but has the flexibility to transport emerging signal types such as LAN/WAN data, video, etc.

- Ability to implement/integrate fault tolerant architectures/topologies in an integrated network design. The standards and equipment have integrated support for this capability.



A) Digital Hierarchy requires expensive multiplexing equipment to add/drop lower level signal because it is asynchronous.



B) SONET can cost effectively add/drop lower level signals because it is synchronous.

Add/Drop Requirements

Figure 6.2-1 A/B

The above SONET features allow simple synchronous bit-interleaving multiplexing techniques that permit cost-effective equipment development and simple interconnect of network elements of varying functionality. The SONET standards define:

- Optical Interface Specifications
- Rate and Format Specifications
- Operational Specifications

6.2.1 SONET Standards

Relevant U.S. standards dealing with SONET include:

ANSI T1.101 Synchronization Interface Standards for Digital Networks.
ANSI T1.106, Digital Hierarchy — Optical Interface Specifications (Single-mode).
ANSI T1.102, Digital Hierarchy — Electrical Interfaces.
SONET Add-drop Multiplex Equipment (SONET ADM) Generic Criteria. TR-TSY-000496, Issue 2 (BELLCORE, September 1989).
Integrated Digital Loop Carrier System Generic Requirements, Objectives, and Interface. TR-TSY-000303, Issue 1 (BELLCORE, September 1986) plus Revisions and Supplements.
Digital Synchronization Network Plan. TA-NPL-000436, Issue 1 (BELLCORE, November 1986).
Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria. TR-TSY-000253, Issue 1 (BELLCORE, September 1989). (A module of TSGR, FR-NWT-000440).
Transport Systems Generic Requirements (TSGR): Common Requirements. TR-TSY-000499, Issue 3 (BELLCORE, December 1989). (A module of TSGR, FR-NWT-000440).
Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria. TA-NWT-000253, Issue 6 (BELLCORE, September 1990), plus Bulletin No. 1, August 1991.
Generic Reliability Assurance Requirements for Fiber Optic Transport Systems. TA-NWT-00418, Issue (BELLCORE, to be issued).

Relevant, ITU-T international recommendations (with essentially the effect of a standard) on SONET/SDH include:

G.702 Digital hierarchy bit rates
G.703 Physical/electrical characteristics of hierarchical digital interfaces
G.707 Synchronous digital hierarchy bit rates
G.708 Network node interface for the synchronous digital hierarchy
G.709 Synchronous multiplexing structure

G.773 Protocol suites for Q interfaces for management of transmission systems
G.781 Structure of recommendations on multiplexing equipment for the synchronous digital hierarchy
G.782 Types and general characteristics of synchronous digital hierarchy multiplexing equipment
G.783 Characteristics of synchronous digital hierarchy multiplexing equipment
G.784 Synchronous digital hierarchy management
G.955 Digital line systems based on the 1.544-Mbps hierarchy on optical-fiber cables
G.956 Digital line systems based on the 2.048-Mbps hierarchy on optical-fiber cables
G.957 Optical interfaces for equipment and systems relating to the synchronous digital hierarchy
G.958 Digital line systems based on the synchronous digital hierarchy for use on optical-fiber cables
G.652 Characteristics of a single-mode optical-fiber cable
G.653 Characteristics of a dispersion-shifted, single-mode, optical-fiber cable
G.654 Characteristics of a 1,500-nm wavelength, loss-minimized single-mode, optical-fiber cable
M.30 Telecommunications management network

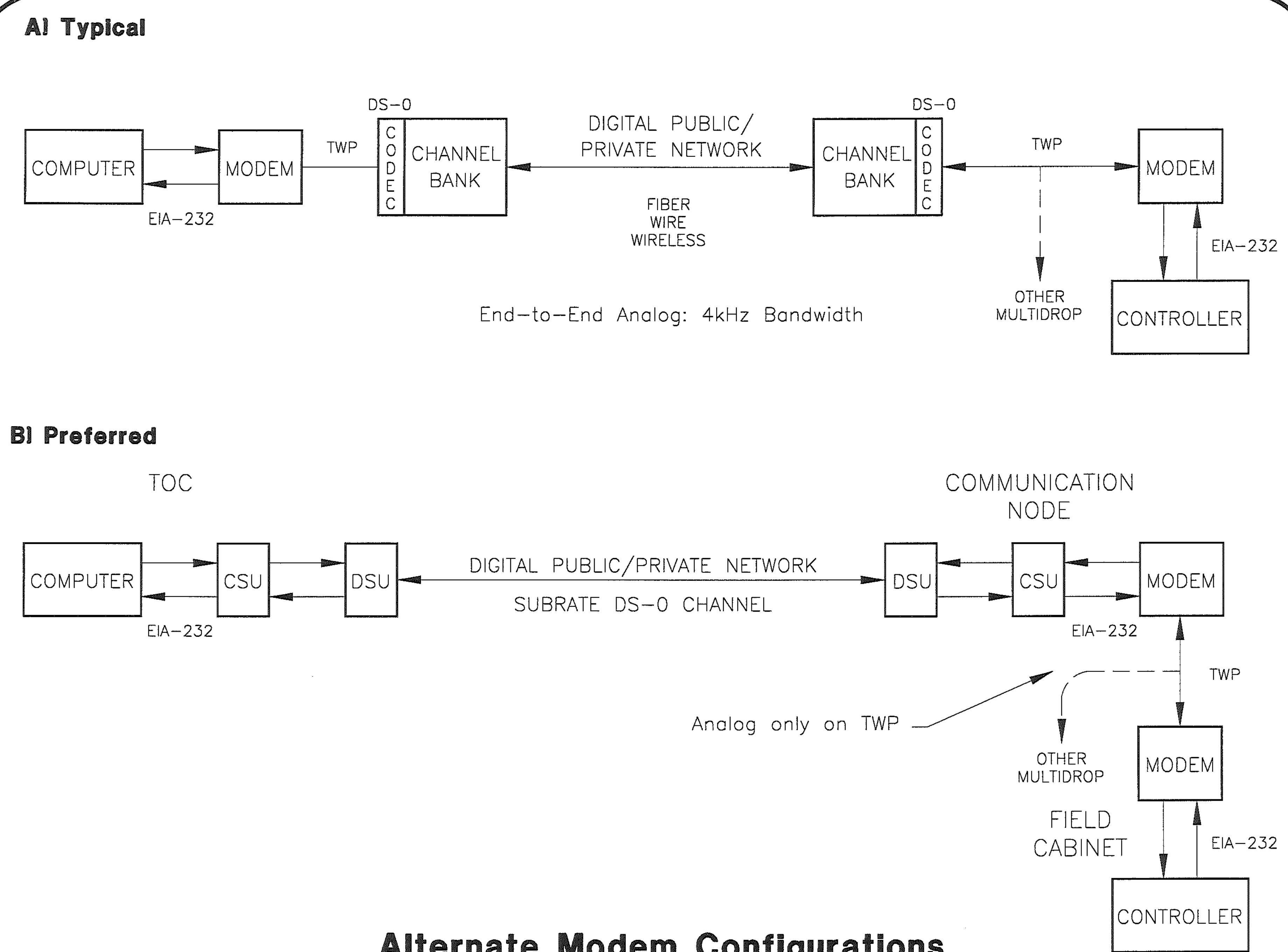
6.3 WIRELINE MODEMS

Wireline modems (MODulate DEModulate) are designed to operate over the analog telephone network as depicted in **Figure 6.3-1**. The digital data input, typically a serial EIA-232, is input to the modem where it is converted to an analog signal.

Historically, the telephone network was analog; however, since the 1950's, the telephone switching and transmission network has been converting to digital.

A voice signal has a typical bandwidth of 3000-3500 Hertz (Hz) covering the spectrum from 100-300 Hz to 3200-3600 Hz. A CODEC in a channel bank low pass filters the signal to less than 4000 Hz, and samples the signal and 8000 samples/second at 8 bits/sample to create a 64 kbps, DS-0, digital signal. The modem signal is analog on the TWP from field cabinet to communication node where it is digitized by the channel bank for switching and transmission.

The TWP is a superior modem channel (for reasonable distances, 1-10 miles) as compared with a combination of TWP and DS-0 digital channel(s). Thus, where possible, it is often advantageous to employ modems only over TWP. **Figure 6.3-1** presents two alternative configurations for operating modems using DS-0, 64 kbps, circuits. The typical configuration (a) has modems at the TOC and field cabinets and creates an equivalent end-to-end analog "voice-like" connection. The preferred configuration (b)



Alternate Modem Configurations

Figure 6.3-1

uses a Subrate DS-0 channel from TOC to communication node, then TWP between analog modems.

The available modem standards and data rates are presented in **Table 6.3-1**. Until the breakup of the RBOCs (Regional Bell Operating Companies) in 1984, U.S. standards were defined by AT&T (or Bell). International standards were defined by ITU (formerly CCITT). The equivalent ITU standards are in parentheses. Since 1984, ITU standards apply both within the U.S. and internationally.

The Model 400 modem that is widely deployed in traditional ITS-related signal systems is the Bell 202 modem with enhancements (e.g., antistreaming). ITS-related applications have not made extensive use of the more recent, higher speed, modems because they do not support the widely deployed multidrop capabilities.

Table 6.3-1

Modem Standards

Standard	Data Rates	Modulation
Bell 103 (V.21)	0 to 300 bps	FSK
Bell 201 (V.26)	1200 & 2400 bps	PSK
Bell 202 (V.23)	1200 bps	FSK
Bell 208 (V.27)	4800 bps	DPSK
Bell 212 (V.22)	1200 bps	DPSK
Bell 209 (V.29)	9600 bps	QAM
V.22 bis	2400 bps	QAM
V.32	4800, 7200 & 9600 bps	QAM
V.32 bis	Same as V.32 plus 12,000 & 14,400 bps	QAM
V.17 (Facsimile)	Same as V.32 bis	QAM
V.32ter	Same as V.32 bis plus 16,800 & 19,200 bps	QAM
V.34	Same as V.32ter plus 21,600, 24,000, 26,400 & 28,800 bps	QAM

6.4 COMMUNICATION INFRASTRUCTURE DESIGN

Communication infrastructure design starts with estimates of communication link capacity requirements which requires the following:

- Identifies sources (origin) of data to be communicated (typically field controllers or TOC's) and location.
- Identifies sinks (destinations) of data (typically TOC or field controllers) and location.
- Identifies message lengths and frequency (i.e., once per second, once per hour, etc.) of transmission.
- Any delay requirements from source to sink of message data.
- Use of the above to calculate link capacity, typically in bits per second.

Fortunately, there exists a history of ITS-related systems so that the above is well known for many data sources as presented in **Table 6.4-1**. In reality, historical data rates have been determined by the availability of wireline modems and data rates supported in multidrop circuits usually with proprietary protocols. The evolution to standard protocols required to support multimodal, integrated multijurisdictional, ITS interoperability requires expanded application message sets, protocol, and associated overhead. **Table 6.4-1** also contains estimates of these required data rates. It should be noted that these message sets and protocol are being defined in the NTCIP protocol as a NEMA-sponsored standard.

By counting, the anticipated number of field devices in an ITS-related system, a preliminary analysis of the composite data load in a system can be obtained. To illustrate, **Table 6.4-2** contains examples of three U.S. signal systems for small, medium, and large cities. Assumptions in **Table 6.4-2** are:

- Each signal controller operates at 2400 bps. (It should be noted that most signal controllers use multidrop configurations of 4-10 drops per circuit. Thus, the loads in the table could be scaled down accordingly; however, future ITS functionality will increase data rates and protocol overheads, so they are presented as is.)
- CCTV cameras operate at 3 Mbps which have been evaluated to provide acceptable full motion video for ITS surveillance applications.

Table 6.4-1

Composite Data Load for Typical Small, Medium, and Large Signal Systems

	Small	Medium	Large
Infrastructure miles	60	246	1000
Equipment Numbers			
Traffic Signal Controllers	150	600	3000
CCTV Camera	15	60	200
Variable Message Signs (VMS)	5	20	50
Distributed Centers	2	3	6
Field Equipment Data Loads			
Traffic Signal Controllers @ 2400 bps	360,000 bps	1,440,000 bps	7,200,000 bps
CCTV Camera @ 3 Mbps	45,000,000 bps	180,000,000 bps	600,000,000 bps
Variable Message Signs @ 2400 bps	12,000 bps	48,000 bps	120,000 bps
Composite Field Equipment Data Loads	45,372,000 bps	181,488,000 bps	607,320,000 bps
Distributed Center Load (@ 155.2 Mbps per Center)	310.4 Mbps	465.6 Mbps	931.2 Mbps
Total Load	355.6 Mbps	647.1 Mbps	1.5385 Gbps

Table 6.4-2

Traditional ITS-related Data
Field Data Sources and Digital Data Rates

ITS-Related Equipment	Historical Data Rates (bps)	Estimated Future Data Rates (bps)
Signal Controller	1200 - 2400	9600 - 28,800
Ramp Meters	1200 - 2400	2400 - 28,800
VMS	1200 - 2400	2400 - 28,800
Weather Stations	2400 - 9600	2400 - 28,800
Camera Control	2400 - 9600	2400 - 28,800
WIM/AVI	1200 - 2400	1200 - 28,800
HAR	3500 Hz Analog 64,000 bps	16,000 - 64,000 bps
R.F./Toll Tags	1200 - 2400	1200 - 500,000
CCTV Cameras Digital Analog	30-45 Mbps (Uncompressed) 6 MHz	3-8 Mbps (Compressed) 6 MHz

- The Variable Message Signs (VMS) operate at 2400 bps, and operate continuously (which *does* overstate their data load impact).

- As will be an ITS requirement, TOC-to-TOC (Distributed Centers) generate a 155.2 Mbps load, a standard SONET OC-3 circuit which is frequently employed. (In addition to ITS data sharing requirements, it is also assumed that a hot-standby mode of operation will be required.)

The composite data load is a reasonable estimate of the data load that must be accommodated at the TOCs and on the backbone links. **Table 6.4-3** summarizes anticipated ITS link loads.

It should be noted that a CCTV camera at 3 Mbps represents the dominant data load. CCTV is an emerging ITS requirement that significantly increases the ITS communication infrastructure requirements.

Table 6.4-3

Anticipated ITS Link Loads

Link	Data Rate
Local Links Data Digital Video Digital Voice	 2400 - 9600 bps 3 - 8 Mbps 2.4 - 64 kbps
Backbone Links (Node-to-Node)	100 - 1000 Mbps (Multiple Distributed Links)
Center-to-Center Links	155.2 Mbps
District-to-Region Links	155.2 Mbps or higher
Region-to-National Links	155.2 Mbps or higher

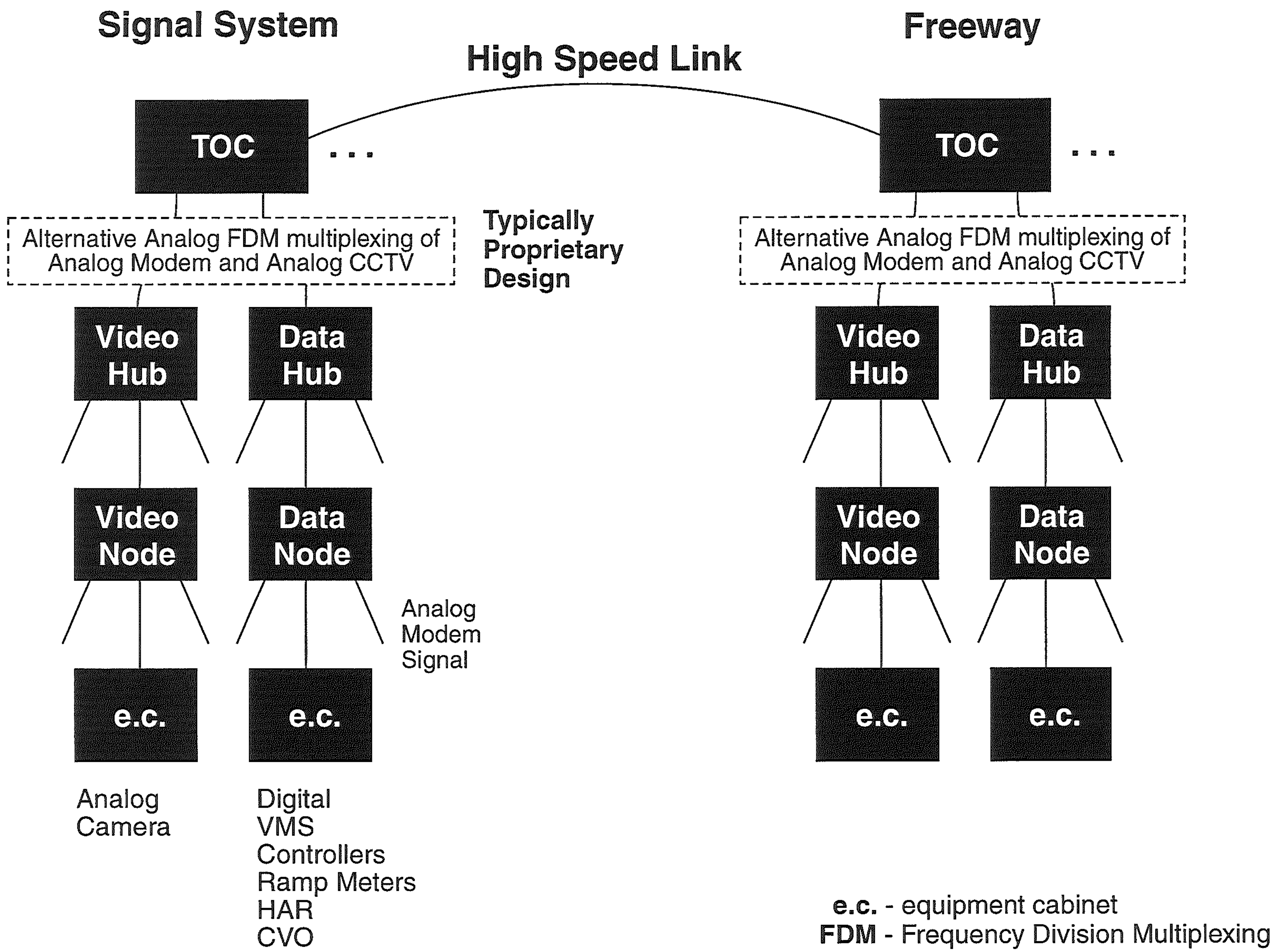
Traditional ITS-related communication systems have employed:

- Overlay of analog video and digital data circuits. The Legacy signal system is on one digital data network with 1200/2400 bps multidrop modems.

- Later emerging CCTV video requirements have often been addressed by a parallel fiber analog frequency division multiplexed (FDM) network.

- In some deployments, further analog FDM has been deployed in hub-to-TOC links to achieve cost-effective multiplexing on longer fiber-based links. This concept is illustrated in **Figure 6.4-1**. It should also be noted that these FDM systems have mostly been non-standard, proprietary systems from a particular vendor.

This overlay of analog video and digital controller data (via analog modems) was cost- effective as the data network was already installed. Legacy ITS-related systems have not provided significant integration and sharing of data among different applications and jurisdictions.



Typical Traditional Deployment of ITS-related Communication Systems

Figure 6.4-1

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Several important considerations will create a need in future ITS systems for integrated ITS communication (sub) systems:

- Many jurisdictions are upgrading or adding systems that include new video and data infrastructures. Usually, except for small systems or where existing facilities are expanded, the most cost-effective communications option is an integrated voice, data, and video network.

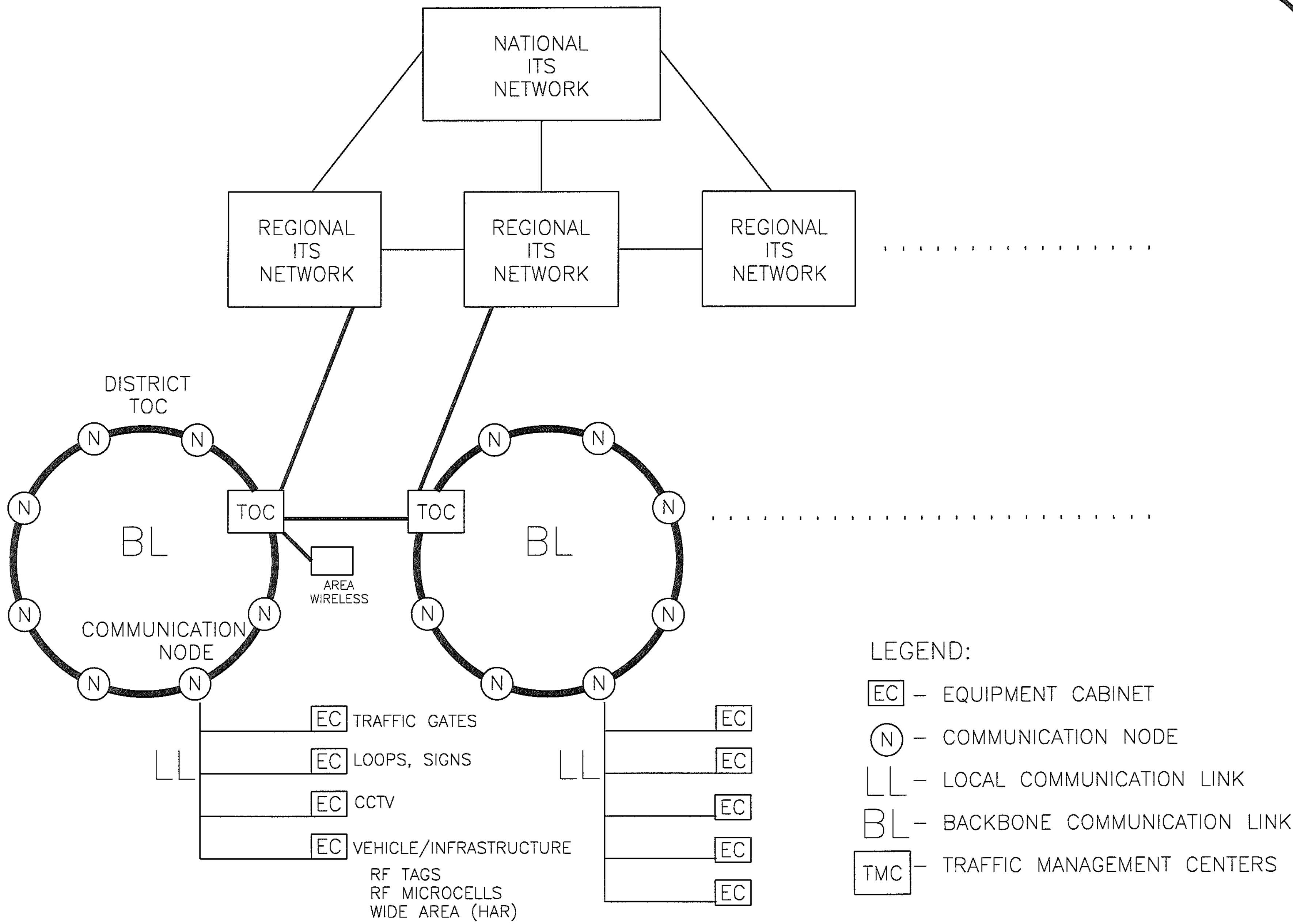
- Video signals should maintain end-to-end 45-60 db S/N (signal-to-noise) for acceptable video quality. Analog video signal gracefully degrades S/N over distance which can not be restored at amplifiers. Digital video signals are completely restored at repeaters (assuming proper link designs) and suffer essentially no degradation over distance. ITS has a requirement for video sharing with multiple, often distant, ITS service providers and jurisdictions.

- Standard interfaces are required for ITS data and video sharing and the emerging MPEG-2 digital video standard is well suited for this purpose as it specifies industry standard DS-1 interfaces.

Figure 6.4-2 illustrates the concept of a digital integrated communications network. In this integrated network, Local Links (LL) connect field devices to communication nodes. At nodes, the various digitized voice, data, and video signals are multiplexed for communication over the higher bit rate backbone network for communication to the TOC. In large networks, a hierarchy of nodes and hubs may be employed with hubs providing more multiplexing and still higher bit rates.

Because MPEG-2 video CODECS are still expensive, video is often maintained as analog from equipment cabinet to node where it is switched and digitized for transmission to the TOC and/or other ITS jurisdictions or services. It should be noted that uncompressed video requires approximately 45 Mbps bit rates (DS-3 rate), while the MPEG-2 requires 3-6 Mbps. As technology is evolving rapidly, ITS video designs should accommodate an anticipated rapid technology evolution to the 3-6 Mbps MPEG-2 standard, which should be very cost-effective.

ITS field devices will be distributed over a geographic area and will generate a geographic data load on the communications infrastructure. Thus, infrastructure design involves developing infrastructure LL and Backbone Links (BL) capability carrying the various data loads over LL to nodes where multiplexing is performed to place the data onto the BL for transmission to the TOCs. Thus, the steps in a communications infrastructure design include:



Representative Future Integrated ITS Communication Network

Figure 6.4–2

- Geographically locating data loads on a map.

- Identifying alternative backbone architecture/topologies to support the data loads. This assumes that links employed are the standards-based subrate, T1 digital hierarchy and SONET OC-n data rates.

- Evaluating required future growth requirements.

- Identifing wireless, wire, and fiber media and terminals capable of supporting the data link loads.

- Identifing multiplexing alternatives.

- Identifing fault tolerant requirements (i.e. rings, redundancy, etc.) and incorporating these into architecture/topologies, multiplexing, alternatives.

- Identifing/specifing protocol requirements and alternatives.

- Performing cost tradeoff and selecting most cost-effective.

As discussed in Section 2.1, ITS is an evolutionary process. Thus, no single communication architecture or topology will be suitable for all implementations. Flexibility must be maintained to accommodate:

- Local jurisdictional requirements and preferences.

- System sizes ranging from those suitable for small cities to those for large metropolitan areas, and those for rural communities.

- Differing geographical requirements.

- Different installation procurement structures.

To illustrate, **Table 6.4-4** provides a summary of the characteristics of urban, suburban, metropolitan, and rural ITS systems. In addition to geographic area size, equipment density, communication link distance, and applicable media, the table lists ITS services anticipated for deployment with each type of system referenced to **Table 2.1-1**.

Table 6.4-4

Characteristics of ITS Systems

Type System	Area Coverage (Radius)	Device/ Controller Density	Average Link Distance	TOC Jurisdiction & Inter-connections	Anticipated Communication Medium(s)	Most Significant Services	Potential Specific ITS Services
Urban	3-5 Miles	High	1-2000 feet	TOC with connection to adjacent Suburban, Freeway, etc TOC	Fiber, Wire, Wireless (lowest installation cost)	ATMS, ATIS, Route Guidance, Emergency Management, Travel Demand Management.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 20, 21, 22
Suburban	10-15 Miles	Medium	2-3000 feet	TOC with connection to adjacent Suburban, Freeway, etc TOC	Fiber, Wire, Wireless (lowest installation cost)	ATMS, ATIS, Route Guidance, Emergency Management, Travel Demand Management.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 20, 21, 22
Metropolitan	30-50 Miles	Varying Urban, Suburban as above Freeways - linear	Varying Urban, Suburban as above Freeways - CCTV 1/2-1 mile controller 1/2-2 miles	MPO TOC with connection to adjacent urban, suburban, etc TOC	Significant Fiber & Wire. Some wireless for lower costs and difficult links. Significant Freeway.	ATMS, ATIS, Route Guidance, Emergency Management, Travel Demand Management, Freeway and CVO.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,19, 20, 21, 22
Rural	100 - 500 Miles	Low	1 mile or more	Usually Freeway TOC with appropriate interconnections.	Extensively wireless for wide area coverage	Emergency/ May-day, CVO, Road Condition	1, 2, 3, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18,19, 20, 21, 22

7.0 CONCLUSIONS AND RECOMMENDATIONS

Section 6.0 presented a general communication strategy based on wireline modems, the T1 digital hierarchy, and SONET. This section will provide specific recommendations on communication strategy(ies) for Arizona.

ADOT has identified plans for 3 TOCs:

- Existing FMS TOC in Phoenix with significant communication infrastructure.
- Planned FMS TOC in Tucson.
- Longer range plans for a TOC in Flagstaff in support of FMS operations along I-40 and I-17 (predominantly rural).

It is recommended that these TOCs serve as regional centers for integrated ITS services. Thus, regional communications infrastructure will be developed for communications from field devices to these TOCs. Similarly, Center-to-Center high speed links should be developed between these centers and to other jurisdictions or regional ITS service centers.

Existing ITS-related systems include:

- Jurisdictional Signal Systems.
- State-owned Freeway Management Systems.
- State-owned Signal Systems.
- WIM/AVC Systems.
- ATR.
- Call Boxes.
- SCAN® Automated Weather Sites.

These systems will be integrated into the eventual statewide ITS communications network.

The selection of ITS services that are applicable and beneficial for Arizona will be an evolutionary process. While the general requirements and anticipated services are being defined, the specific services and required feature sets still need definition. This is to be expected as the national architecture(s) and services are still being defined. Thus, the communications infrastructure for Arizona needs to be modular, scalable, and expandable to cost-effectively support evolution.

7.1 STATEWIDE NETWORK

The statewide communications network will interconnect regional TOCs and is anticipated to require the following capabilities:

- Share ITS-related data among ITS services and jurisdictions.
- Provide off-hour and backup TOC capabilities.
- Provide private long distance services between local exchanges for lower cost dial-up access to functions such as kiosks, VMS, etc.
  Integrate data for statewide ITS services.
- Provide standard interfaces to the commercial network where most cost-effective.
- Provide communication for other state functions.

The cost to install a statewide fiber network would be excessive. Generic unit cost estimates for an installed fiber cable plant are:

- $3/ft. direct bury, aerial, and existing conduit.
  $9/ft. in new conduit.

These cost figures assume no unreasonable right-of-way installation requirements such as:

- Jack and bore under streets, etc.
- Hostile terrain such as canyons, rivers, mountains, etc.
- Right-of-way constraints.

As an example, consider I-40 in Northern Arizona:

- 340 miles.
- Assume $3/ft. direct bury.
- Cable Plant Cost: $5.4M (single cable with 24 fiber).

In addition, depending on the fault tolerant strategy employed (such as rings or redundant fiber), the cost could double.

ADOT has initiated plans to construct, through creative public/private partnership, a fiber backbone system in the interstate right-of-way. The state proposes to offer private organizations access to the right-of-way for installation of a fiber-based infrastructure that would be used to provide commercial telecommunication services with a revenue stream. In exchange, ADOT would gain access to communications infrastructure that might include:

- Dark fiber.
- Fiber bandwidth as DS-n and/or OC-n circuits.

ADOT indicates that state statutes have been amended to allow such private/public partnerships and that the initial planning phase is complete. The next phase is a study to define:

- Communications infrastructure requirements including equipment requirements.
- Required/desirable contractual agreements.

General recommendations for the shared private/public infrastructure include:

- State-owned dark fiber with state-owned splice closures as the preferred option, since this will allow ADOT to control reliability, expandability, maintainability, and hidden costs.

- State access points to the fiber backbone should be carefully planned and negotiated in the agreement. Otherwise, expensive backhaul or additional communications facilities might be required, depending on density and/or location of ITS-related services.

- The fiber cable plant should be procured to support data rates anticipated to be supported by commercial fiber terminals vendors over the next 10-20 years. Currently, OC-192, 10 Gbps terminals are beginning to be deployed.

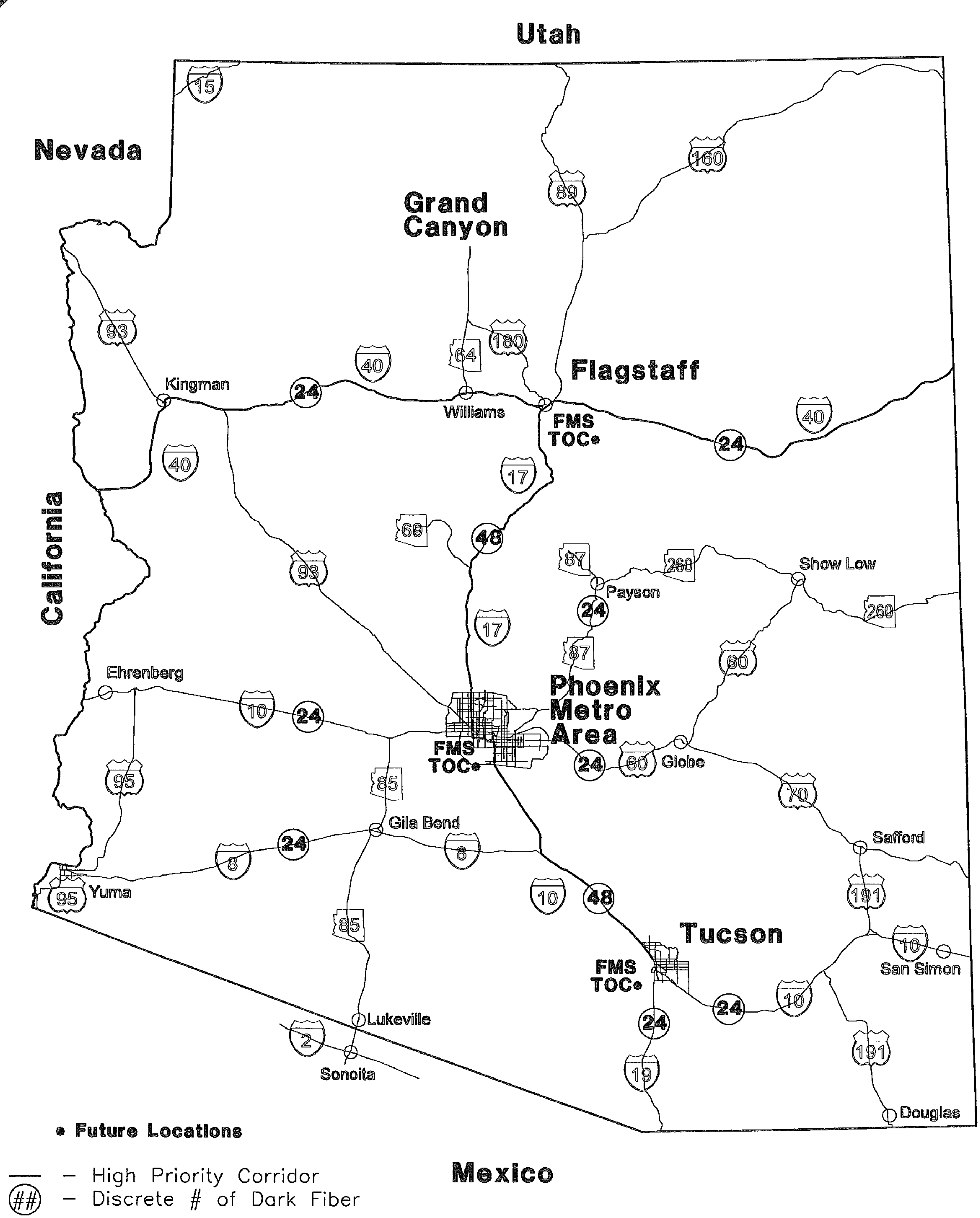
- Careful consideration should be given to the fiber architecture. Rings and other topologies are often deployed to provide fault tolerant capabilities as supported by fiber terminal manufacturers.

Figure 7.1-1 is a suggested ring architecture. Since no natural state ring opportunity exists, a folded ring might be necessary.

7.2 METROPOLITAN AREA RECOMMENDATIONS

The metropolitan areas include:

- City of Phoenix/Maricopa County.
- City of Tucson/Pima County.
- City of Flagstaff/Coconino County.



Proposed Private/Public Fiber Route Priorities

Figure 7.1–1

Communication strategies for metropolitan areas should be consistent statewide. The ADOT FMS in Phoenix in concert with the Maricopa County ITS Strategic Plan provides an excellent model.

The design of the ADOT FMS has evolved since the late 1980s. As was common during this timeframe, the FMS communication system consists of:

- Twisted Wire Pair (TWP) from communication node to field equipment cabinets via Model 400, 2400 bps, modems for low-speed data.

- An overlay fiber system for CCTV video from CCTV equipment cabinets to communication nodes.

- A Frequency Division Multiplexer (FDM) for fiber transmission of voice, data, and video from communication nodes to the TOC.

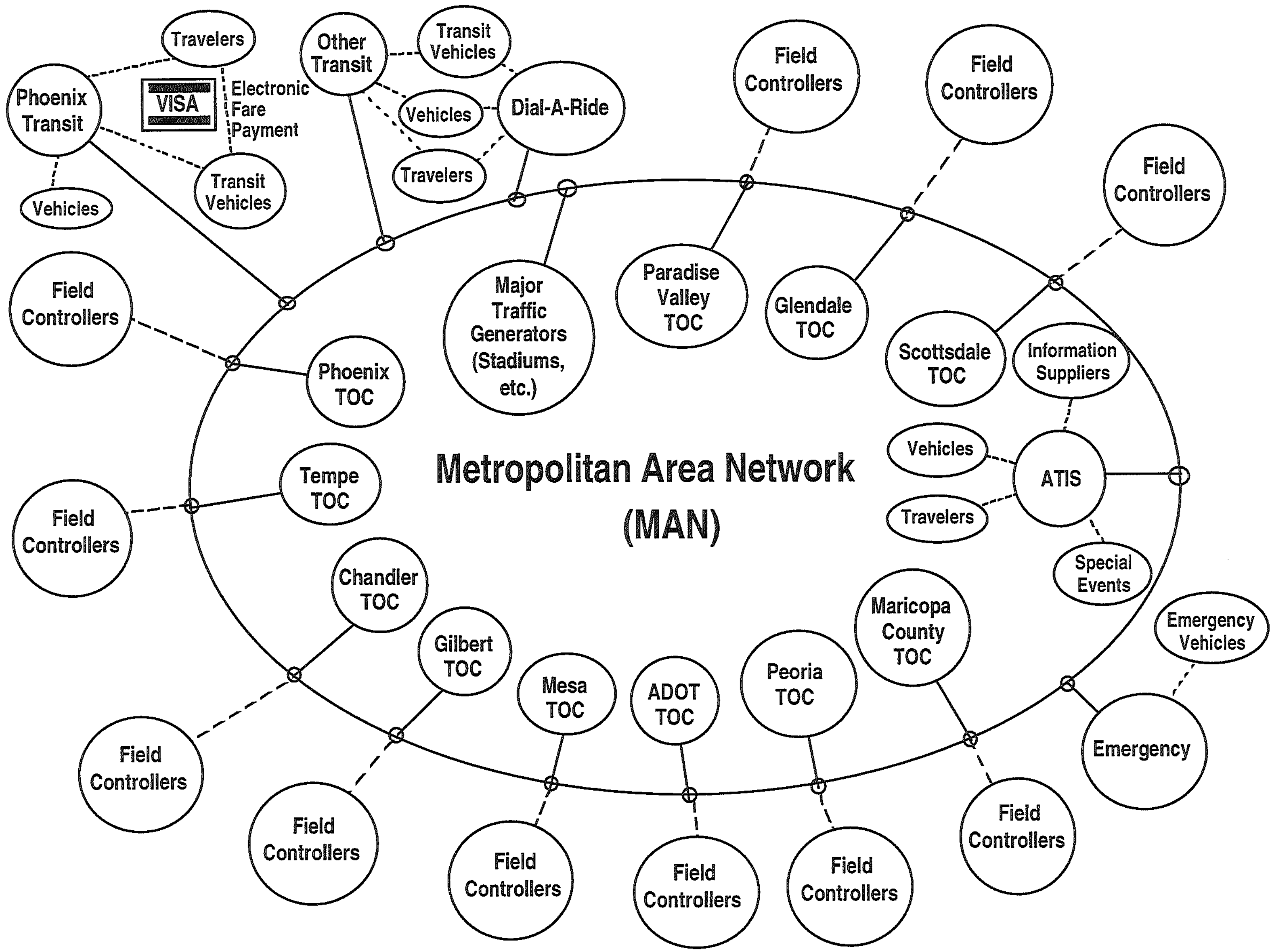
This FDM multiplexer is a non-standard proprietary design that is not well suited to serve as an integrated ITS communication system. Although the FDM terminals do not support the emerging T1/SONET hierarchy of standards, the Single Mode Fiber Optic (SMFO) cable plant should be capable of supporting T1/SONET terminal equipment. The FMS communication subsystem will require an evolutionary upgrade to a standards- based architecture.

The system-level communications architecture recommended and approved by steering committee agencies for the Maricopa County Strategic Plan is presented in **Figure 7.2-1**. The goal of the architecture is to permit the many agency and jurisdictional stakeholders to share a communications infrastructure; however, local jurisdictional control, or authorized shared control, must be effectively accommodated. This can be accomplished with a physical network architecture presented in **Figure 7.2-2**. In this architecture, SONET hubs provide interfaces to:

- The Maricopa County regional network.
- Local jurisdictional gateways to field equipment (e.g., signal systems).
- Local jurisdictional TOC.

The gateways serve in a natural manner as multiplexing field nodes/hubs and provide these additional capabilities:

- Priority control of jurisdiction's infrastructure by the jurisdiction.
- Shared control and/or data sharing when authorized by a jurisdiction.
- Multiplexing of existing and/or new low speed communication links.
- Multiplexing of CCTV video signals.



Peer-to-Peer with Permissive Control and Centralized ATIS Maricopa County Architecture

Figure 7.2-1

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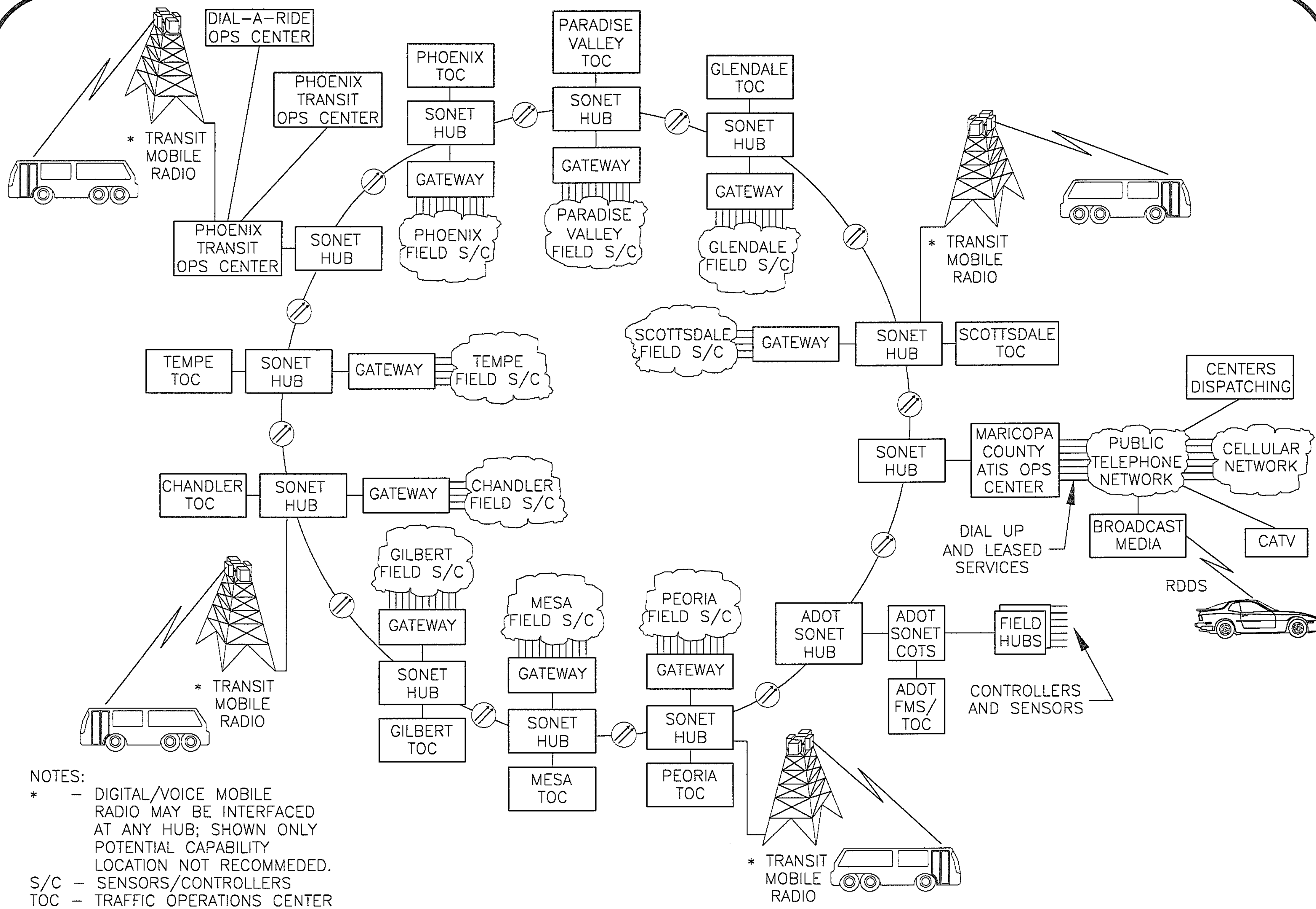


Overall Physical Network Architecture

(Maricopa County Strategic ITS Plan)

Figure 7.2–2

- Capability to support integrated priority corridors consisting of signal system(s) and FMS.

As the leader of the Maricopa County ITS Strategic Plan Team, Kimley-Horn and Associates, Inc., strongly endorses its standards-based philosophy with permissive local control. The concepts should be disseminated to other metropolitan areas (e.g., Tucson, Flagstaff, etc.) for review and creative critique.

7.3 URBAN/SUBURBAN RECOMMENDATIONS

The urban and suburban ITS-related capabilities have traditionally consisted primarily of local signal systems. While operational functionalities follow NEMA TS-1/TS-2 standards, the communications subsystems have not followed standards.

National Transportation Control/ITS Protocol (NTCIP) is an emerging NEMA communications standard for these applications. It should be noted that NTCIP has sufficient flexibility to allow local jurisdictions to accommodate local operational needs and requirements. An outreach/support program should be supported by ADOT to help local jurisdictions understand and evolve to NTCIP in a statewide compatible manner.

7.4 RURAL RECOMMENDATIONS

Rural requirements are the least scoped of ITS service capabilities. Additionally, communications infrastructure design is difficult because of low population density and resulting frequent lack of commercial or private communications facilities.

ADOT has identified the following Arizona rural ITS-related requirements:

- Kiosk all I-40 for ATIS functions.
- Emerging FMS capabilities along I-40 initially with eventual expansion to other interstates.
- VMS signs.
- Video cameras.
- Various WIM/AVC and ATR functions located along interstates and state highways.
- Highway Advisory Radio (HAR).
- Roadway Weather Information System.

Except for FMS capabilities, all these functions are not real-time capabilities and can therefore be addressed by:

- Local processing (typically PC-based), statistic data collection, and database maintenance.

- Periodic updates by dialup modem connection to synchronizing databases.
- Generally requiring data rates below the 28.8 kbps capabilities of low-cost computer and modem technology.

In general, these are most cost-effectively addressed by standard PC technology and standard wireline modems. Depending on the frequency of update, these are probably most cost-effectively addressed by commercial dialup lines. The expense could rise if long distance calls are required; however, several alternatives exist.

- If ADOT develops a statewide communications infrastructure, long distance charges can be avoided by using the state's private network with off-net local dialing capability. (See **Figure 7.4-1**)

- Local connections can use standard commercial telephone, cellular, or data services (e.g., CDPD, RAM, ARDIS).

- Local connections can also be made via private local networks where available and cost-effective.

- The recent FCC Report and Order (R&O) on refarming and the Association of Public-Safety Communications Officials (APCO) Project 25 standard offer interesting possibilities, but are too new to adequately scope at this time due to uncertainty of frequency allocations by the FCC; however, these activities should be closely monitored as they provide an excellent opportunity for interoperational radios between agencies.

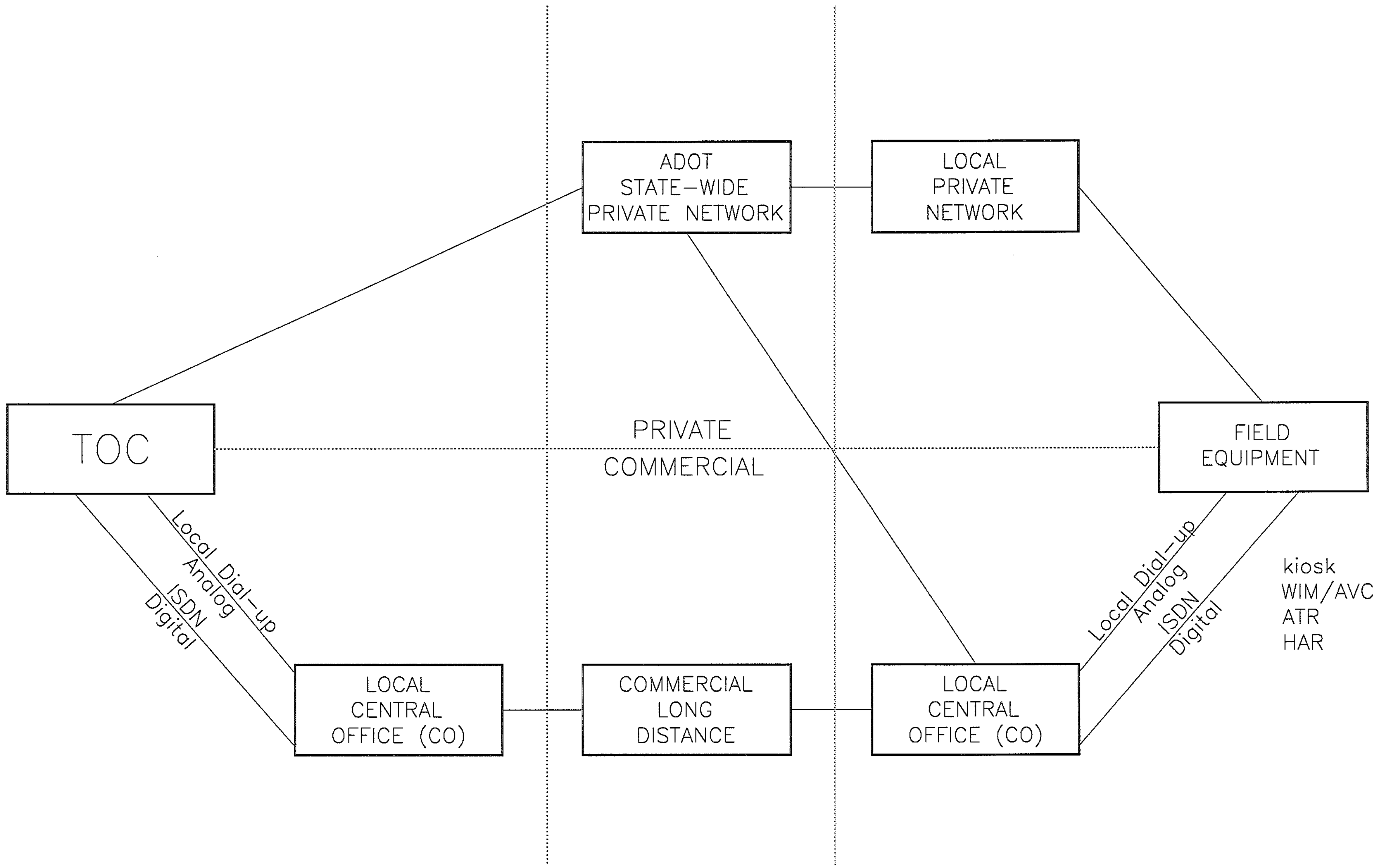
- Commercial ISDN services offer interesting possibilities, if the data rates required (e.g., graphics at kiosks) exceed modem capabilities; however, they will be more costly.

7.5 EMERGENCY OPERATIONS RECOMMENDATIONS

Currently, emergency operations for motorists are addressable by cellular communication. The coverage area for U.S. West within the State of Arizona is presented on **Figure 7.5-1**. Future ITS plans include considerations of integrated wireless devices in vehicles with driver activated emergency buttons. When and if available, a network of location receivers, perhaps satellite, or some combination will be required.

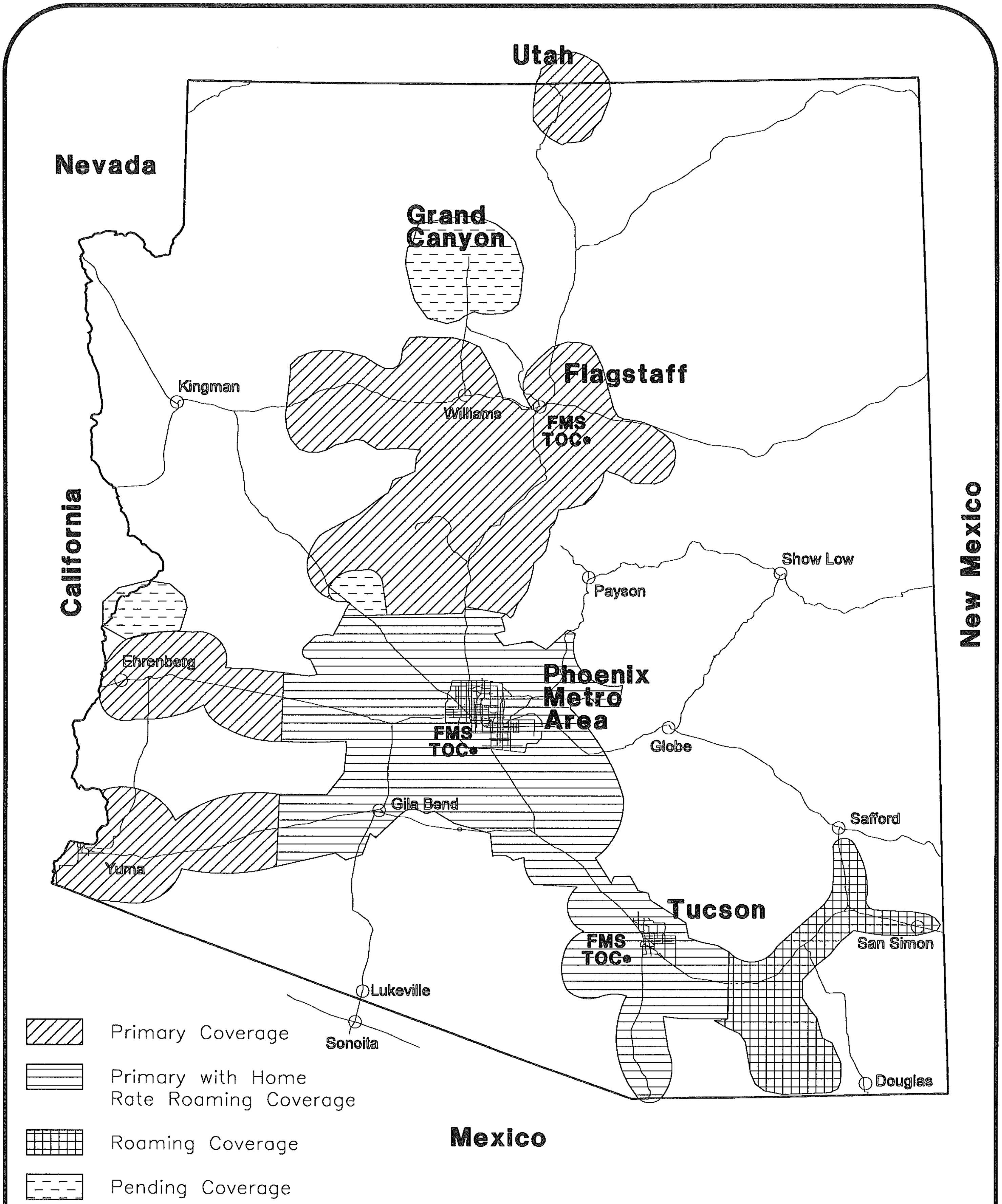
Other emergency services in the Phoenix FMS include standard dialup services to one or more of the following:

- Police.
- Ambulance.



Alternate Rural Network Options

Figure 7.4-1



U.S. West Cellular Coverage Area

Figure 7.5–1

- Towing.
- Fire.
- Interoperational radios.

Private network links can be provided where more efficient expedient, connections are required. An integrated data message capability might prove advantageous.

The APCO-25 standard for public safety radios might provide a method for achieving interoperability of radios between agencies.

7.6 ATMS/ATIS

Advanced Traffic Management Systems (ATMS) represent an ITS concept that expands and enhances the capabilities of traditional signal systems and freeway management systems. ATMS provide for adaptive signal control and integrated corridor management. ATMS will have the sensors, including surveillance video, to generate real-time data on the performance of the transportation infrastructure. Based on this data, response strategies can be developed that include:

- Traffic control (signal systems, ramp meters, VMS, etc.).
- Incident management.

Advanced Traveler Information Systems (ATIS) make use of ATMS data and provide potential and actual drivers/travelers with the following information:

- Pre-trip travel information including route guidance.
- Route guidance information.
- Demand management and operations.
- Transit options.

The delivery of this information to the public is (will be) accomplished by several communication options:

- Dialup computer data service.
- Internet (increasingly Web Page).
- HAR.
- Subcarriers on commercial broadcast radio.

The T1 digital hierarchy and SONET hierarchy provide the standard interfaces required to interact with these services and equipment.

7.7 GENERAL RECOMMENDATIONS

7.7.1 NTCIP

NTCIP (National Transportation Control/ITS Communication Protocol) is based on the standard modular 7 layer Open Systems Interconnect (OSI) Reference Model of the International Standards Organization as depicted in **Figure 7.7.1-1**.

NTCIP, as currently defined, consolidates the upper three layers into a single application layer. The NEMA/FHWA Standards Committee has announced plans to provide application layer message sets for:

- Signal Systems.
- Variable Message Signs (VMS).
- Ramp Metering.
- Camera Control.
- Highway Advisory Radio (HAR).
- Others, as identified.

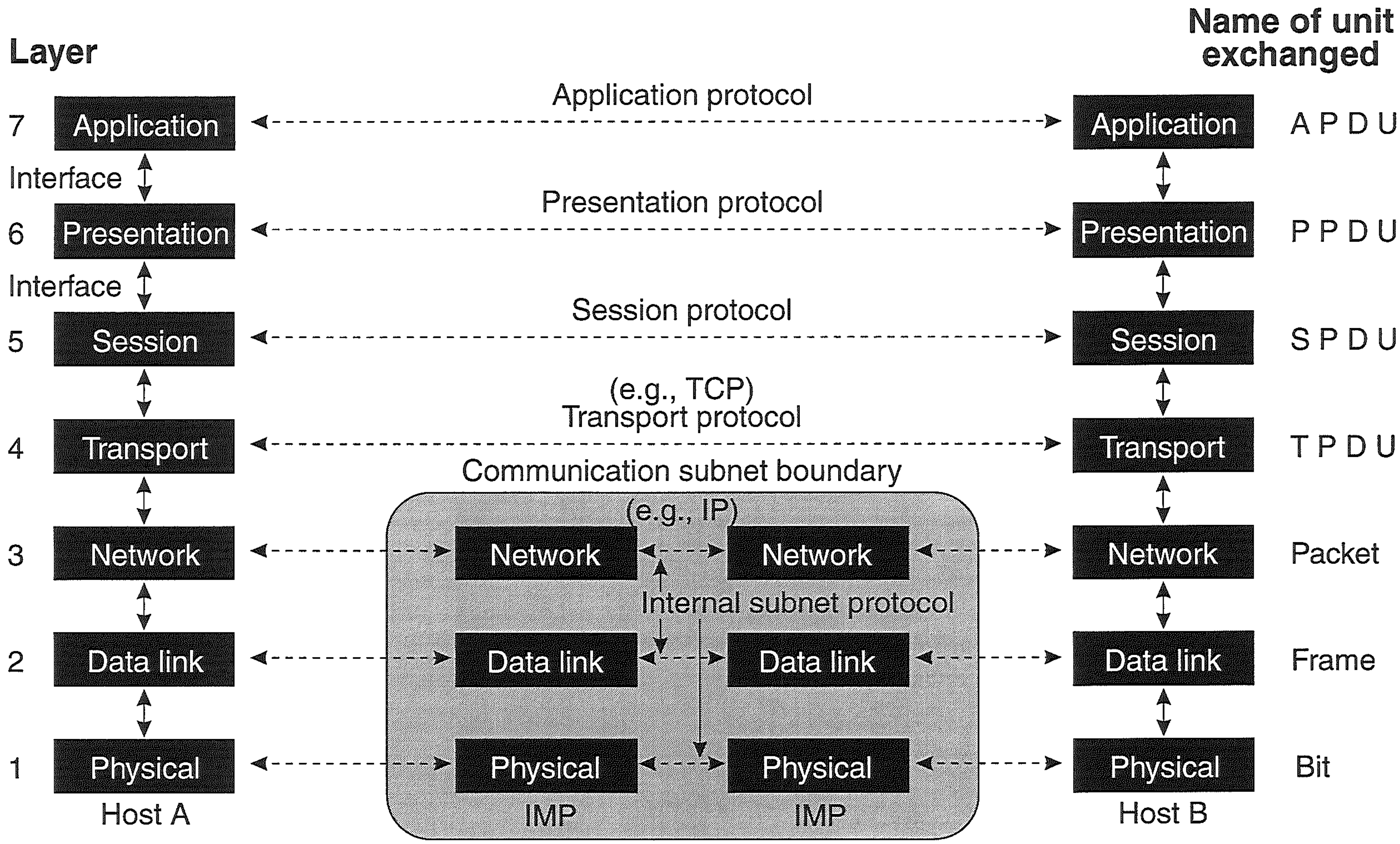
The lower four layers will be based on widely deployed international protocols:

1. Layer 4 Transportation Control Protocol (TCP).
2. Layer 3 Internet Protocol (IP).
3. Layer 2 HDLC.
4. Layer 1 EIA-232.

Layers 3 and 4 are widely deployed TCP/IP protocols that are becoming increasingly popular in support of the internet. Additionally, it should be noted that EIA-232 is a standard for physical layers only, and as such requires higher layer protocols to define interoperable standards. NTCIP provides the definition of these higher layers.

HDLC and TCP/IP will be slightly modified as required to support transportation applications. In particular, a Class B protocol suite will be the first application protocol stack adopted and will be tailored to support the Legacy 1200/2400 bps, multidrop, modem installed base. The low bit rate of these installations requires a scaled down protocol which the Class B protocol defines.

It is recommended that ADOT adopt NTCIP and include appropriate wording in procurement specifications to support evolution as NTCIP is expanded to address multiple applications and modern, higher-speed, links.



IMP - Interface Message Processor
PDU - Protocol Data Unit

Note: Communication Subnet may be private or public network and it may be point-to-point, store, and forward, etc.

International Standards Organization (ISO): Open Systems Interconnect (OSI) Reference Model

Figure 7.7.1-1

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7.7.2 Radio Networks

The FCC's refarming rules are oriented to allow existing equipment to be replaced on normal life-cycle timelines; however, rechannelization of the various bands could open significant communication capacity for new applications.

Additionally, the FCC will define new frequency coordination (and allocation) procedures for the affected bands. ADOT should be proactive in its planning and frequency requests/applications to the FCC. Otherwise, ADOT interests may not achieve appropriate priority. An immediate study to define a strategy is recommended.

The APCO-25 standard for digital radios for public safety radios is responsive to the FCC's refarming rules. APCO-25 offers an interesting standard for achieving interoperability of the radio systems of various state agencies.

APPENDIX A

Arizona Commercial Services

Century Yuma Cellular Corporation
770 East 32nd Street
Yuma, Arizona 85365
520/344-5200
Counties Served: IAP, YUM
Number of Customers: Not Available

Gila River Cellular General Partnership
1851 North Center
Casa Grande, Arizona 85222
520/836-1200
Counties Served: GIL, PIN
Number of Customers: Not Available

Metro Mobile CTS of Phoenix, Inc.
7975 North Hayden Road, Suite A-200
Scottsdale, Arizona 85258
908/306-7236
Counties Served: MAR, GIL, PIN, COC
Number of Customers: Not Available

Satellite Cellular Systems Partnership
550 Cervantes Drive
Henderson, Nevada 89014-4003
702/436-0349
Counties Served: MOH
Number of Customers: Not Available

TUCELL Partnership
3440 South Palo Verde, Suite 142
Tucson, Arizona 85713
520/740-9100
Counties Served: PIM
Number of Customers: Not Available

U.S. West Newvector Group, Inc.
429 North 30th Street
Phoenix, Arizona 85008
602/275-9458
Counties Served: MAR, SAN
Number of Customers: Not Available

Coconino, Arizona RSA Limited Partnership
20 Quartz Drive
Sedona, Arizona 86351
520/709-4900
Counties Served: COC, YAV
Number of Customers: Not Available

Jaybar Communications
7975 N. Hayden Road, Suite A-200
Scottsdale, Arizona 85258
908/306-7259
Counties Served: COCH
Number of Customers: Not Available

Mohave Cellular Limited Partnership
P.O. Box 6727
Kingman, Arizona 86402
520/716-4636
Counties Served: MOH
Number of Customers: Not Available

Smith Bagley, Inc.
1080 Holcomb Bridge Road, Bldg. 100, #200
Roswell, Georgia 30076
202/822-9195
Counties Served: APA, NAV
Number of Customers: Not Available

Tucson Cellular Telephone Company
998 South Cherry Avenue
Tucson, Arizona 85719
908/306-7236
Counties Served: PIMA
Number of Customers: Not Available

Valley Telecommunications Company
P.O. Box 1099
Willcox, Arizona 85644-1099
520/384-2960
Counties Served: COCH, GRA, GRE
Number of Customers: 3,392

Yuma, Arizona RSA Limited Partnership
251 W. 24th Street, Suite 141
Yuma, Arizona 85364
520/344-2199
Counties Served: YUM
Number of Customers: Not Available

TOTAL = 13

Allnet Communication Services, Inc.
30300 Telegraph Road
Bingham Farms, Michigan 48025-4510
810/647-6920
Counties Served: MAR, PIM, APA, GIL, LAP, NAV
Number of Customers: Not Available

AT&T Communications of the Mountain States, Inc.
2800 N. Central Avenue, Suite 828
Phoenix, Arizona 85004
415/442-3302
Counties Served: Statewide
Number of Customers: Not Available

Citizens Utilities Company - Arizona Telephone Division
P.O. Box 3801 / High Ridge Park
Stamford, Connecticut 06905
203/753-4051
Counties Served: MOH
Number of Customers: 40,225

Contel of California, Inc. - Arizona
5300 District Boulevard
Bakersfield, California 93313
805/833-2481
Counties Served: LAP
Number of Customers: 6,876

MCI Telecommunications Corporation
201 Spear St., 9th Fl/Attn: Patrick Chow
San Francisco, California 94105
415/978-1129
Counties Served: Statewide
Number of Customers: Not Available

Arizona Telephone Company
2236 W. Shangri-La Road
Phoenix, Arizona 85029
602/944-2265
Counties Served: GIL, MAR, PIM, COC
Number of Customers: 2,245

Citizens Telecommunications Company of Arizona
P.O. Box 3801 / High Ridge Park
Stamford, Connecticut 06905
203/537-6602
Counties Served: APA, COC, GIL, GRE, NAV
Number of Customers: Not Available

Citizens Utilities Rural Company, Inc.
P.O. Box 3801 / High Ridge Park
Stamford, Connecticut 06905
203/753-4051
Counties Served: MOH
Number of Customers: 60,027

Copper Valley Telephone, Inc.
P.O. Box 970
Willcox, Arizona 85644
520/384-2231
Counties Served: COCH, GRE
Number of Customers: Not Available

Midvale Telephone Exchange, Inc.
P.O. Box 1269
Benson, Arizona 85602
520/586-2645
Counties Served: COCH, PIM, PIN
Number of Customers: 130

Navajo Communications Company, Inc.
P.O. Drawer 6000
Window Rock Arizona 86515
520/871-3789
Counties Served: COC, APA, NAV
Number of Customers: 12, 065

South Central Utah Telephone Association, Inc.
P.O. Box 555
Escalante, Utah 84726
801/826-4211
Counties Served: MOH
Number of Customers: 6,000

Sprint Communications Company L.P.
901 E. 104th Street
Kansas City, Missouri 64131
816/854-7941
Counties Served: Statewide
Number of Customers: Not Available

U.S. West Communications, Inc.
3033 N. Third Street, Room 606
Phoenix, Arizona 85012
520/630-8221
Counties Served: Statewide
Number of Customers: 2,158,166

Valley Telephone Cooperative, Inc.
P.O. Box 970
Willcox, Arizona 85644
520/384-2231
Counties Served: GRA, COCH
Number of Customers: 1,775

Rio Virgin Telephone Company
P.O. Box 299
Mesquite, Nevada 89024
702/346-5211
Counties Served: MOH
Number of Customers: 570

Southwestern Telephone Company
P.O. Box 663
Salome, Arizona 85348
520/859-3456
Counties Served: LAP
Number of Customers: 3,556

Table Top Telephone Company, Inc.
P.O. Box 50097
Phoenix, Arizona 85076-0097
520/387-5600
Counties Served: APA, COC, MAR, PIM, YAV
Number of Customers: Not Available

Universal Telephone Company of Southwest
P.O. Box 4065
Monroe, Louisiana 71211-4065
318/388-9729
Counties Served: NAV, NM-SANM, MCK, CIB, SANF
Number of Customers: 1,343

TOTAL = 19

REGULATED UTILITY LIST
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Effective
8-17-95

American Network Exchange, Inc.
101 Park Avenue
New York, New York 10178
000/000-0000
Counties Served: Statewide
Number of Customers: Not Available

Capital Network System, Inc.
600 Congress Avenue, Suite 1360
Austin, Texas 78701
512/477-6566
Counties Served: Statewide
Number of Customers: Not Available

Conquest Operator Services
Arizona
000/000-0000
Counties Served: Statewide
Number of Customers: Not Available

Express Tel
324 South State Street, Suite 308
Salt Lake City, Utah 84111
801/521-0200
Counties Served:
Number of Customers: Not Available

Oncor Communications, Inc.
Arizona
000/000-0000
Counties Served:
Number of Customers: Not Available

Stenocall
1515 Avenue J
Lubbock, Texas 79401
806/762-0811
Counties Served:
Number of Customers: Not Available

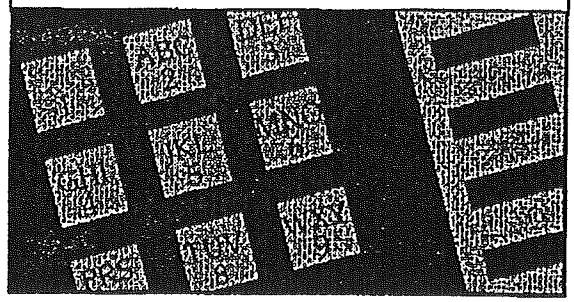
U.S. Long Distance, inc.
9311 San Pedro, Suite 300
San Antonio, Texas 78216
210/525-9009
Counties Served: Statewide
Number of Customers: Not Available

U.S. Osiris Corporation
8828 Stemmons Freeway, Suite 212
Dallas, Texas 75247-3721
214/640-4110
Counties Served: Statewide
Number of Customers: Not Available

TOTAL = 8

Single Line ISDN Service

USWEST®
Facts by FAX



Definitions

- NPA is the Area Code
- NXX is the first three digits of the telephone number.
- Wire Center is the telephone central office that serves a particular area code and telephone number.
- NI is National ISDN. A YES in the column indicates that ISDN capability is available. A NO indicates that ISDN is not available at this time. A date indicates that as of the date shown National ISDN is available.
- NUM CHG is Number Change. A YES in the column indicates that the ISDN telephone number will have a different NXX than the NXX on the reference line. This is because the ISDN capability is provided by another switching entity and is served remotely.

  A NO in the column means that the ISDN telephone number will have the same NXX as shown on the reference line.

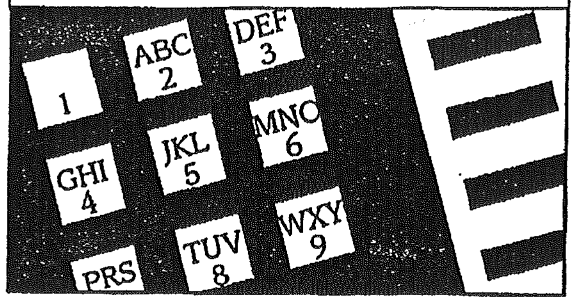
  A blank in the column means that ISDN is not available at this location.
- 64 CCC is 64 Clear Channel Capability. A YES indicates that 64 CCC is available from this location. A NO or blank indicates that 64 CCC is not available at this time.
- X.75p is X.75' or X.75 prime. A YES indicates that X.75' is available at this location. There is a gateway through the packet switch network. A NO or blank indicates that this capability does not exist at this time.

USWEST®
COMMUNICATIONS

Arizona ISDN Single Line Service Availability

By Wire Center

USWEST®
Facts by FAX



NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
505	358	DUNCAN	NO			
520	685	AGUILA	NO			
520	387	AJO	NO			
520	637	ASHFORK	NO			
520	633	BAGDAD	NO			
520	586	BENSON	NO			
520	432	BISBEE	NO			
520	567	CAMP VERDE	NO			
520	421	CASA GRANDE	NO			
520	426	CASA GRANDE	NO			
520	836	CASA GRANDE	NO			
520	299	CATALINA	NO			
520	529	CATALINA	NO			
520	577	CATALINA	NO			
520	636	CHINO VALLEY	NO			
520	865	CLIFTON	NO			
520	723	COOLIDGE	NO			
520	825	CORONADO	NO			
520	579	CORTARO	YES	NO	YES	NO
520	744	CORTARO	YES	NO	YES	NO
520	634	COTTONWOOD-MAIN	NO			
520	639	COTTONWOOD-MAIN	NO			
520	646	COTTONWOOD-SOUTH	NO			
520	512	CRAYCROFT	NO			
520	513	CRAYCROFT	NO			
520	519	CRAYCROFT	NO			
520	557	CRAYCROFT	NO			
520	570	CRAYCROFT	NO			
520	571	CRAYCROFT	NO			
520	703	CRAYCROFT	NO			
520	745	CRAYCROFT	NO			

Arizona ISDN Single Line Service Availability
By Wire Center *(continued)*

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
520	747	CRAYCROFT	NO			
520	748	CRAYCROFT	NO			
520	750	CRAYCROFT	NO			
520	790	CRAYCROFT	NO			
520	364	DOUGLAS	NO			
520	805	DOUGLAS	NO			
520	357	DUDLEYVILLE	NO			
520	359	DUNCAN	NO			
520	642	ELFRIDA	NO			
520	466	ELOY	NO			
520	522	FLAGSTAFF EAST	YES	NO	YES	NO
520	526	FLAGSTAFF EAST	YES	NO	YES	NO
520	527	FLAGSTAFF EAST	YES	NO	YES	NO
520	523	FLAGSTAFF MAIN	YES	NO	YES	NO
520	556	FLAGSTAFF MAIN	YES	NO	YES	NO
520	679	FLAGSTAFF MAIN	YES	NO	YES	NO
520	773	FLAGSTAFF MAIN	YES	NO	YES	NO
520	774	FLAGSTAFF MAIN	YES	NO	YES	NO
520	779	FLAGSTAFF MAIN	YES	NO	YES	NO
520	525	FLAGSTAFF SOUTH	NO			
520	868	FLORENCE	NO			
520	292	FLOWING-WELLS	NO			
520	293	FLOWING-WELLS	NO			
520	690	FLOWING-WELLS	NO			
520	696	FLOWING-WELLS	NO			
520	887	FLOWING-WELLS	NO			
520	888	FLOWING-WELLS	NO			
520	683	GILA BEND	NO			
520	402	GLOBE	NO			
520	425	GLOBE	NO			
520	638	GRAND CANYON	NO			
520	393	GREEN VALLEY	NO			
520	625	GREEN VALLEY	NO			
520	648	GREEN VALLEY	NO			
520	356	HAYDEN	NO			
520	288	JOSEPH CITY	NO			
520	363	KEARNY	NO			
520	487	MAMMOTH	NO			
520	616	MARANA	NO			
520	682	MARANA SOUTH	NO			
520	568	MARICOPA	NO			
520	632	MAYER	NO			
520	473	MIAMI	NO			
520	576	MOUNT LEMMON	NO			
520	286	MUNDS PARK	NO			
520	287	NOGALES	NO			

Arizona ISDN Single Line Service Availability
By Wire Center *(continued)*

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
520	281	NOGALES MIDWAY	NO			
520	761	NOGALES MIDWAY	NO			
520	896	ORACLE	NO			
520	608	PAGE	NO			
520	645	PAGE	NO			
520	366	PALOMINAS	NO			
520	394	PATAGONIA	NO			
520	455	PATOGONIA ELGIN	NO			
520	472	PAYSON	NO			
520	474	PAYSON	NO			
520	485	PIMA	NO			
520	476	PINE	NO			
520	772	PRESCOTT EAST	NO			
520	775	PRESCOTT EAST	NO			
520	442	PRESCOTT MAIN	YES	NO	YES	NO
520	445	PRESCOTT MAIN	YES	NO	YES	NO
520	717	PRESCOTT MAIN	YES	NO	YES	NO
520	771	PRESCOTT MAIN	YES	NO	YES	NO
520	776	PRESCOTT MAIN	YES	NO	YES	NO
520	778	PRESCOTT MAIN	YES	NO	YES	NO
520	290	RINCON	NO			
520	296	RINCON	NO			
520	298	RINCON	NO			
520	721	RINCON	NO			
520	722	RINCON	NO			
520	733	RINCON	NO			
520	751	RINCON	NO			
520	885	RINCON	NO			
520	886	RINCON	NO			
520	348	SAFFORD	NO			
520	428	SAFFORD	NO			
520	720	SAINT DAVID	NO			
520	475	SAN CARLOS	NO			
520	688	SANDERS	NO			
520	385	SAN MANUEL	NO			
520	204	SEDONA-MAIN	YES	NO	YES	NO
520	282	SEDONA-MAIN	YES	NO	YES	NO
520	284	SEDONA-SOUTH	NO			
520	452	SIERRA VISTA-MN	YES	NO	NO	NO
520	458	SIERRA VISTA-MN	YES	NO	NO	NO
520	459	SIERRA VISTA-MN	YES	NO	NO	NO
520	515	SIERRA VISTA-MN	YES	NO	NO	NO
520	533	SIERRA VISTA-MN	YES	NO	NO	NO
520	538	SIERRA VISTA-MN	YES	NO	NO	NO
520	456	SIERRA VISTA NO	NO			
520	378	SIERRA VISTA SO	NO			

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
520	627	SOMERTON	NO			
520	424	STANFIELD	NO			
520	689	SUPERIOR	NO			
520	749	TANQUE VERDE	YES	NO	YES	NO
520	760	TANQUE VERDE	YES	NO	YES	NO
520	457	TOMBSTONE	NO			
520	478	TONTO CREEK	NO			
520	398	TUBAC	NO			
520	318	TUCSON-EAST	NO			
520	321	TUCSON-EAST	NO			
520	322	TUCSON-EAST	NO			
520	323	TUCSON-EAST	NO			
520	324	TUCSON-EAST	NO			
520	325	TUCSON-EAST	NO			
520	326	TUCSON-EAST	NO			
520	327	TUCSON-EAST	NO			
520	795	TUCSON-EAST	NO			
520	881	TUCSON-EAST	NO			
520	388	TUCSON-MAIN	YES	NO	YES	NO
520	617	TUCSON-MAIN	YES	NO	YES	NO
520	620	TUCSON-MAIN	YES	NO	YES	NO
520	621	TUCSON-MAIN	YES	NO	YES	NO
520	622	TUCSON-MAIN	YES	NO	YES	NO
520	623	TUCSON-MAIN	YES	YES	YES	NO
520	624	TUCSON-MAIN	YES	NO	YES	NO
520	626	TUCSON-MAIN	YES	YES	YES	NO
520	628	TUCSON-MAIN	YES	NO	YES	NO
520	629	TUCSON-MAIN	YES	NO	YES	NO
520	670	TUCSON-MAIN	YES	NO	YES	NO
520	694	TUCSON-MAIN	YES	NO	YES	NO
520	695	TUCSON-MAIN	YES	NO	YES	NO
520	740	TUCSON-MAIN	YES	NO	YES	NO
520	770	TUCSON-MAIN	YES	NO	YES	NO
520	791	TUCSON-MAIN	YES	NO	YES	NO
520	792	TUCSON-MAIN	YES	NO	YES	NO
520	798	TUCSON-MAIN	YES	NO	YES	NO
520	882	TUCSON-MAIN	YES	NO	YES	NO
520	884	TUCSON-MAIN	YES	NO	YES	NO
520	218	TUCSON-NORTH	YES	YES	YES	NO
520	291	TUCSON-NORTH	YES	YES	YES	NO
520	297	TUCSON-NORTH	YES	YES	YES	NO
520	410	TUCSON-NORTH	YES	YES	YES	NO
520	446	TUCSON-NORTH	YES	YES	YES	NO
520	469	TUCSON-NORTH	YES	YES	YES	NO
520	544	TUCSON-NORTH	YES	YES	YES	NO
520	575	TUCSON-NORTH	YES	YES	YES	NO

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
520	712	TUCSON-NORTH	YES	YES	YES	NO
520	742	TUCSON-NORTH	YES	YES	YES	NO
520	793	TUCSON-NORTH	YES	YES	YES	NO
520	797	TUCSON-NORTH	YES	YES	YES	NO
520	294	TUCSON-SOUTH	YES	YES	YES	NO
520	295	TUCSON-SOUTH	YES	YES	YES	NO
520	573	TUCSON-SOUTH	YES	YES	YES	NO
520	741	TUCSON-SOUTH	YES	YES	YES	NO
520	746	TUCSON-SOUTH	YES	YES	YES	NO
520	794	TUCSON-SOUTH	YES	YES	YES	NO
520	799	TUCSON-SOUTH	YES	YES	YES	NO
520	806	TUCSON-SOUTH	YES	YES	YES	NO
520	889	TUCSON-SOUTH	YES	YES	YES	NO
520	574	TUCSON SE	NO			
520	663	TUCSON SE	NO			
520	578	TUCSON SOUTHWEST	NO			
520	822	TUCSON SOUTHWEST	NO			
520	883	TUCSON SOUTHWEST	NO			
520	743	TUCSON WEST	NO			
520	647	VAIL NORTH	NO			
520	762	VAIL SOUTH	NO			
520	785	WELLTON	NO			
520	463	WHITLOW	NO			
520	684	WICKENBURG	NO			
520	384	WILLCOX	NO			
520	422	WILLIAMS	NO			
520	635	WILLIAMS	NO			
520	289	WINSLOW	NO			
520	427	YARNELL	NO			
520	687	YORK VALLEY	NO			
520	462	YOUNG	NO			
520	328	YUMA-MAIN	NO			
520	329	YUMA-MAIN	NO			
520	343	YUMA-MAIN	NO			
520	539	YUMA-MAIN	NO			
520	782	YUMA-MAIN	NO			
520	783	YUMA-MAIN	NO			
520	317	YUMA-SOUTHEAST	NO			
520	341	YUMA-SOUTHEAST	NO			
520	344	YUMA-SOUTHEAST	NO			
520	726	YUMA-SOUTHEAST	NO			
520	305	YUMA FORTUNA	NO			
520	342	YUMA FORTUNA	NO			
602	685	AGUILA	NO			

USWEST® COMMUNICATIONS

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	387	AJO	NO			
602	637	ASHFORK	NO			
602	633	BAGDAD	NO			
602	214	BEARDSLEY	YES	NO	YES	NO
602	546	BEARDSLEY	YES	NO	YES	NO
602	584	BEARDSLEY	YES	NO	YES	NO
602	975	BEARDSLEY	YES	NO	YES	NO
602	586	BENSON	NO			
602	432	BISBEE	NO			
602	374	BLACK CANYON	NO			
602	386	BUCKEYE	NO			
602	567	CAMP VERDE	NO			
602	421	CASA GRANDE	NO			
602	426	CASA GRANDE	NO			
602	836	CASA GRANDE	NO			
602	299	CATALINA	NO			
602	529	CATALINA	NO			
602	577	CATALINA	NO			
602	488	CAVE CREEK	YES	YES	YES	NO
602	715	CHANDLER-MAIN	YES	NO	YES	NO
602	732	CHANDLER-MAIN	YES	NO	YES	NO
602	786	CHANDLER-MAIN	YES	NO	YES	NO
602	812	CHANDLER-MAIN	YES	NO	YES	NO
602	814	CHANDLER-MAIN	YES	NO	YES	NO
602	821	CHANDLER-MAIN	YES	NO	YES	NO
602	899	CHANDLER-MAIN	YES	NO	YES	NO
602	917	CHANDLER-MAIN	YES	NO	YES	NO
602	963	CHANDLER-MAIN	YES	NO	YES	NO
602	802	CHANDLER-SOUTH	YES	NO	YES	NO
602	895	CHANDLER-SOUTH	YES	NO	YES	NO
602	496	CHANDLER-WEST	YES	NO	YES	NO
602	554	CHANDLER-WEST	YES	NO	YES	NO
602	592	CHANDLER-WEST	YES	NO	YES	NO
602	598	CHANDLER-WEST	YES	NO	YES	NO
602	893	CHANDLER-WEST	YES	NO	YES	NO
602	920	CHANDLER-WEST	YES	NO	YES	NO
602	940	CHANDLER-WEST	YES	NO	YES	NO
602	961	CHANDLER-WEST	YES	NO	YES	NO
602	636	CHINO VALLEY	NO			
602	865	CLIFTON	NO			
602	925	COLDWATER	NO			
602	932	COLDWATER	NO			
602	723	COOLIDGE	NO			
602	825	CORONADO	NO			
602	579	CORTARO	YES	NO	YES	NO

USWEST®
COMMUNICATIONS

Arizona ISDN Single Line Service Availability
By Wire Center *(continued)*

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	744	CORTARO	YES	NO	YES	NO
602	634	COTTONWOOD-MAIN	NO			
602	639	COTTONWOOD-MAIN	NO			
602	646	COTTONWOOD-SOUTH	NO			
602	512	CRAYCROFT	NO			
602	513	CRAYCROFT	NO			
602	557	CRAYCROFT	NO			
602	570	CRAYCROFT	NO			
602	571	CRAYCROFT	NO			
602	703	CRAYCROFT	NO			
602	745	CRAYCROFT	NO			
602	747	CRAYCROFT	NO			
602	748	CRAYCROFT	NO			
602	750	CRAYCROFT	NO			
602	790	CRAYCROFT	NO			
602	434	DEER VALLEY NORTH	YES	NO	YES	NO
602	492	DEER VALLEY NORTH	YES	NO	YES	NO
602	516	DEER VALLEY NORTH	YES	NO	YES	NO
602	580	DEER VALLEY NORTH	YES	NO	YES	NO
602	581	DEER VALLEY NORTH	YES	NO	YES	NO
602	582	DEER VALLEY NORTH	YES	NO	YES	NO
602	780	DEER VALLEY NORTH	YES	NO	YES	NO
602	869	DEER VALLEY NORTH	YES	NO	YES	NO
602	879	DEER VALLEY NORTH	YES	NO	YES	NO
602	364	DOUGLAS	NO			
602	805	DOUGLAS	NO			
602	357	DUDLEYVILLE	NO			
602	359	DUNCAN	NO			
602	642	ELFRIDA	NO			
602	466	ELOY	NO			
602	522	FLAGSTAFF EAST	YES	NO	YES	NO
602	526	FLAGSTAFF EAST	YES	NO	YES	NO
602	527	FLAGSTAFF EAST	YES	NO	YES	NO
602	523	FLAGSTAFF MAIN	YES	NO	YES	NO
602	556	FLAGSTAFF MAIN	YES	NO	YES	NO
602	679	FLAGSTAFF MAIN	YES	NO	YES	NO
602	773	FLAGSTAFF MAIN	YES	NO	YES	NO
602	774	FLAGSTAFF MAIN	YES	NO	YES	NO
602	779	FLAGSTAFF MAIN	YES	NO	YES	NO
602	525	FLAGSTAFF SOUTH	NO			
602	868	FLORENCE	NO			
602	292	FLOWING-WELLS	NO			
602	293	FLOWING-WELLS	NO			
602	690	FLOWING-WELLS	NO			
602	696	FLOWING-WELLS	NO			
602	887	FLOWING-WELLS	NO			

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	888	FLOWING-WELLS	NO			
602	816	FORT MCDOWELL	YES	NO	YES	NO
602	837	FORT MCDOWELL	YES	NO	YES	NO
602	683	GILA BEND	NO			
602	497	GILBERT	YES	NO	YES	YES
602	545	GILBERT	YES	NO	YES	YES
602	549	GILBERT	YES	NO	YES	YES
602	813	GILBERT	YES	NO	YES	YES
602	892	GILBERT	YES	NO	YES	YES
602	926	GILBERT	YES	NO	YES	YES
602	435	GLENDALE-MAIN	NO			
602	842	GLENDALE-MAIN	NO			
602	915	GLENDALE-MAIN	NO			
602	930	GLENDALE-MAIN	NO			
602	931	GLENDALE-MAIN	NO			
602	934	GLENDALE-MAIN	NO			
602	937	GLENDALE-MAIN	NO			
602	939	GLENDALE-MAIN	NO			
602	402	GLOBE	NO			
602	425	GLOBE	NO			
602	638	GRAND CANYON	NO			
602	625	GREEN VALLEY	NO			
602	648	GREEN VALLEY	NO			
602	356	HAYDEN	NO			
602	987	HGLY QUEEN CREEK	NO			
602	988	HIGLEY	NO			
602	288	JOSEPH CITY	NO			
602	363	KEARNY	NO			
602	856	LITCHFIELD PARK	NO			
602	935	LITCHFIELD PARK	NO			
602	487	MAMMOTH	NO			
602	682	MARANA SOUTH	NO			
602	568	MARICOPA	NO			
602	632	MAYER	NO			
602	461	MESA-MAIN	YES	YES	YES	NO
602	464	MESA-MAIN	YES	YES	YES	NO
602	644	MESA-MAIN	YES	NO	YES	NO
602	649	MESA-MAIN	YES	NO	YES	NO
602	655	MESA-MAIN	YES	NO	YES	NO
602	668	MESA-MAIN	YES	NO	YES	NO
602	827	MESA-MAIN	YES	YES	YES	NO
602	833	MESA-MAIN	YES	YES	YES	NO
602	834	MESA-MAIN	YES	YES	YES	NO
602	835	MESA-MAIN	YES	YES	YES	NO
602	844	MESA-MAIN	YES	YES	YES	NO
602	890	MESA-MAIN	YES	YES	YES	NO

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	898	MESA-MAIN	YES	YES	YES	NO
602	962	MESA-MAIN	YES	YES	YES	NO
602	964	MESA-MAIN	YES	YES	YES	NO
602	969	MESA-MAIN	YES	YES	YES	NO
602	473	MIAMI	NO			
602	576	MOUNT LEMMON	NO			
602	286	MUNDS PARK	NO			
602	465	NEW RIVER	NO			
602	287	NOGALES	NO			
602	281	NOGALES MIDWAY	NO			
602	761	NOGALES MIDWAY	NO			
602	896	ORACLE	NO			
602	608	PAGE	NO			
602	645	PAGE	NO			
602	366	PALOMINAS	NO			
602	394	PATAGONIA	NO			
602	455	PATOGONIA ELGIN	NO			
602	472	PAYSON	NO			
602	474	PAYSON	NO			
602	678	PHNX U S WEST DIRECT	YES	NO	YES	YES
602	872	PHOENIX-BETHANY WEST	YES	NO	YES	NO
602	877	PHOENIX-BETHANY WEST	YES	NO	YES	NO
602	404	PHOENIX-CACTUS	YES	NO	YES	NO
602	482	PHOENIX-CACTUS	YES	NO	YES	NO
602	493	PHOENIX-CACTUS	YES	NO	YES	NO
602	494	PHOENIX-CACTUS	YES	NO	YES	NO
602	569	PHOENIX-CACTUS	YES	NO	YES	NO
602	788	PHOENIX-CACTUS	YES	NO	YES	NO
602	867	PHOENIX-CACTUS	YES	NO	YES	NO
602	953	PHOENIX-CACTUS	YES	NO	YES	NO
602	971	PHOENIX-CACTUS	YES	NO	YES	NO
602	992	PHOENIX-CACTUS	YES	NO	YES	NO
602	996	PHOENIX-CACTUS	YES	NO	YES	NO
602	203	PHOENIX-EAST	NO			
602	209	PHOENIX-EAST	NO			
602	210	PHOENIX-EAST	NO			
602	220	PHOENIX-EAST	NO			
602	225	PHOENIX-EAST	NO			
602	231	PHOENIX-EAST	NO			
602	236	PHOENIX-EAST	NO			
602	244	PHOENIX-EAST	NO			
602	267	PHOENIX-EAST	NO			
602	273	PHOENIX-EAST	NO			
602	275	PHOENIX-EAST	NO			
602	302	PHOENIX-EAST	NO			
602	306	PHOENIX-EAST	NO			

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	389	PHOENIX-EAST	NO			
602	392	PHOENIX-EAST	NO			
602	613	PHOENIX-EAST	NO			
602	681	PHOENIX-EAST	NO			
602	913	PHOENIX-EAST	NO			
602	914	PHOENIX-EAST	NO			
602	460	PHOENIX-FOOTHILLS	YES	NO	YES	NO
602	375	PHOENIX-GREENWAY	YES	YES	YES	YES
602	436	PHOENIX-GREENWAY	YES	NO	YES	YES
602	439	PHOENIX-GREENWAY	YES	YES	YES	YES
602	504	PHOENIX-GREENWAY	YES	NO	YES	YES
602	543	PHOENIX-GREENWAY	YES	YES	YES	YES
602	547	PHOENIX-GREENWAY	YES	NO	YES	YES
602	548	PHOENIX-GREENWAY	YES	NO	YES	YES
602	588	PHOENIX-GREENWAY	YES	YES	YES	YES
602	789	PHOENIX-GREENWAY	YES	YES	YES	YES
602	843	PHOENIX-GREENWAY	YES	YES	YES	YES
602	862	PHOENIX-GREENWAY	YES	YES	YES	YES
602	863	PHOENIX-GREENWAY	YES	YES	YES	YES
602	866	PHOENIX-GREENWAY	YES	YES	YES	YES
602	938	PHOENIX-GREENWAY	YES	YES	YES	YES
602	942	PHOENIX-GREENWAY	YES	YES	YES	YES
602	978	PHOENIX-GREENWAY	YES	YES	YES	YES
602	993	PHOENIX-GREENWAY	YES	YES	YES	YES
602	237	PHOENIX-LAVEEN	NO			
602	201	PHOENIX-MAIN	YES	YES	YES	YES
602	202	PHOENIX-MAIN	YES	YES	YES	YES
602	205	PHOENIX-MAIN	YES	YES	YES	YES
602	208	PHOENIX-MAIN	YES	YES	YES	YES
602	213	PHOENIX-MAIN	YES	YES	YES	YES
602	219	PHOENIX-MAIN	YES	YES	YES	YES
602	223	PHOENIX-MAIN	YES	YES	YES	YES
602	226	PHOENIX-MAIN	YES	YES	YES	YES
602	227	PHOENIX-MAIN	YES	YES	YES	YES
602	229	PHOENIX-MAIN	YES	YES	YES	YES
602	238	PHOENIX-MAIN	YES	YES	YES	YES
602	239	PHOENIX-MAIN	YES	YES	YES	YES
602	250	PHOENIX-MAIN	YES	YES	YES	YES
602	251	PHOENIX-MAIN	YES	YES	YES	YES
602	252	PHOENIX-MAIN	YES	YES	YES	YES
602	253	PHOENIX-MAIN	YES	YES	YES	YES
602	254	PHOENIX-MAIN	YES	YES	YES	YES
602	255	PHOENIX-MAIN	YES	YES	YES	YES
602	256	PHOENIX-MAIN	YES	YES	YES	YES
602	257	PHOENIX-MAIN	YES	YES	YES	YES
602	258	PHOENIX-MAIN	YES	YES	YES	YES

USWEST® COMMUNICATIONS

Arizona ISDN Single Line Service Availability
By Wire Center *(continued)*

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	259	PHOENIX-MAIN	YES	YES	YES	YES
602	261	PHOENIX-MAIN	YES	YES	YES	YES
602	262	PHOENIX-MAIN	YES	YES	YES	YES
602	270	PHOENIX-MAIN	YES	YES	YES	YES
602	271	PHOENIX-MAIN	YES	YES	YES	YES
602	310	PHOENIX-MAIN	YES	YES	YES	YES
602	313	PHOENIX-MAIN	YES	NO	YES	YES
602	340	PHOENIX-MAIN	YES	YES	YES	YES
602	360	PHOENIX-MAIN	YES	YES	YES	YES
602	365	PHOENIX-MAIN	YES	NO	YES	YES
602	379	PHOENIX-MAIN	YES	NO	YES	YES
602	382	PHOENIX-MAIN	YES	NO	YES	YES
602	401	PHOENIX-MAIN	YES	YES	YES	YES
602	407	PHOENIX-MAIN	YES	YES	YES	YES
602	408	PHOENIX-MAIN	YES	YES	YES	YES
602	409	PHOENIX-MAIN	YES	YES	YES	YES
602	416	PHOENIX-MAIN	YES	YES	YES	YES
602	417	PHOENIX-MAIN	YES	YES	YES	YES
602	420	PHOENIX-MAIN	YES	YES	YES	YES
602	440	PHOENIX-MAIN	YES	YES	YES	YES
602	450	PHOENIX-MAIN	YES	YES	YES	YES
602	495	PHOENIX-MAIN	YES	YES	YES	YES
602	498	PHOENIX-MAIN	YES	YES	YES	YES
602	506	PHOENIX-MAIN	YES	NO	YES	YES
602	514	PHOENIX-MAIN	YES	NO	YES	YES
602	519	PHOENIX-MAIN	YES	YES	YES	YES
602	528	PHOENIX-MAIN	YES	YES	YES	YES
602	534	PHOENIX-MAIN	YES	YES	YES	YES
602	542	PHOENIX-MAIN	YES	NO	YES	YES
602	590	PHOENIX-MAIN	YES	YES	YES	YES
602	591	PHOENIX-MAIN	YES	YES	YES	YES
602	593	PHOENIX-MAIN	YES	YES	YES	YES
602	594	PHOENIX-MAIN	YES	NO	YES	YES
602	597	PHOENIX-MAIN	YES	NO	YES	YES
602	817	PHOENIX-MAIN	YES	YES	YES	YES
602	245	PHOENIX-MARYVALE	NO			
602	247	PHOENIX-MARYVALE	NO			
602	846	PHOENIX-MARYVALE	NO			
602	848	PHOENIX-MARYVALE	NO			
602	849	PHOENIX-MARYVALE	NO			
602	873	PHOENIX-MARYVALE	NO			
602	583	PHOENIX-MID RIVERS	YES	YES	YES	NO
602	815	PHOENIX-MID RIVERS	YES	YES	YES	NO
602	876	PHOENIX-MID RIVERS	YES	YES	YES	NO
602	933	PHOENIX-MID RIVERS	YES	YES	YES	NO
602	972	PHOENIX-MID RIVERS	YES	YES	YES	NO

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	974	PHOENIX-MID RIVERS	YES	YES	YES	NO
602	977	PHOENIX-MID RIVERS	YES	YES	YES	NO
602	207	PHOENIX-NORTH	YES	NO	YES	YES
602	217	PHOENIX-NORTH	YES	YES	YES	YES
602	221	PHOENIX-NORTH	YES	NO	YES	YES
602	222	PHOENIX-NORTH	YES	YES	YES	YES
602	230	PHOENIX-NORTH	YES	YES	YES	YES
602	234	PHOENIX-NORTH	YES	YES	YES	YES
602	235	PHOENIX-NORTH	YES	YES	YES	YES
602	240	PHOENIX-NORTH	YES	YES	YES	YES
602	241	PHOENIX-NORTH	YES	YES	YES	YES
602	248	PHOENIX-NORTH	YES	YES	YES	YES
602	263	PHOENIX-NORTH	YES	YES	YES	YES
602	264	PHOENIX-NORTH	YES	YES	YES	YES
602	265	PHOENIX-NORTH	YES	YES	YES	YES
602	266	PHOENIX-NORTH	YES	YES	YES	YES
602	274	PHOENIX-NORTH	YES	YES	YES	YES
602	277	PHOENIX-NORTH	YES	YES	YES	YES
602	279	PHOENIX-NORTH	YES	YES	YES	YES
602	280	PHOENIX-NORTH	YES	YES	YES	YES
602	285	PHOENIX-NORTH	YES	YES	YES	YES
602	351	PHOENIX-NORTH	YES	YES	YES	YES
602	406	PHOENIX-NORTH	YES	YES	YES	YES
602	490	PHOENIX-NORTH	YES	NO	YES	YES
602	530	PHOENIX-NORTH	YES	YES	YES	YES
602	605	PHOENIX-NORTH	YES	NO	YES	YES
602	630	PHOENIX-NORTH	YES	NO	YES	YES
602	631	PHOENIX-NORTH	YES	YES	YES	YES
602	640	PHOENIX-NORTH	YES	NO	YES	YES
602	650	PHOENIX-NORTH	YES	YES	YES	YES
602	651	PHOENIX-NORTH	YES	NO	YES	YES
602	664	PHOENIX-NORTH	YES	NO	YES	YES
602	665	PHOENIX-NORTH	YES	NO	YES	YES
602	224	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	381	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	468	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	503	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	508	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	521	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	553	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	801	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	808	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	840	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	852	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	912	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	952	PHOENIX-NORTHEAST	YES	NO	YES	NO

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	954	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	955	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	956	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	957	PHOENIX-NORTHEAST	YES	NO	YES	NO
602	242	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	246	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	249	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	336	PHOENIX-NORTHWEST	YES	NO	YES	YES
602	433	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	589	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	841	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	864	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	973	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	995	PHOENIX-NORTHWEST	YES	YES	YES	YES
602	706	PHOENIX-PECOS	YES	NO	YES	NO
602	759	PHOENIX-PECOS	YES	NO	YES	NO
602	412	PHOENIX-PEORIA	NO			
602	486	PHOENIX-PEORIA	NO			
602	878	PHOENIX-PEORIA	NO			
602	979	PHOENIX-PEORIA	NO			
602	232	PHOENIX-SOUTH	NO			
602	243	PHOENIX-SOUTH	NO			
602	268	PHOENIX-SOUTH	NO			
602	276	PHOENIX-SOUTH	NO			
602	304	PHOENIX-SOUTH	NO			
602	414	PHOENIX-SOUTHEAST	YES	YES	YES	YES
602	431	PHOENIX-SOUTHEAST	YES	YES	YES	YES
602	437	PHOENIX-SOUTHEAST	YES	YES	YES	YES
602	438	PHOENIX-SOUTHEAST	YES	YES	YES	YES
602	470	PHOENIX-SOUTHEAST	YES	YES	YES	YES
602	331	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	371	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	395	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	861	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	870	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	906	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	943	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	944	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	997	PHOENIX-SUNNYSLOPE	YES	YES	YES	YES
602	233	PHOENIX-WEST	YES	NO	YES	YES
602	269	PHOENIX-WEST	YES	YES	YES	YES
602	272	PHOENIX-WEST	YES	YES	YES	YES
602	278	PHOENIX-WEST	YES	YES	YES	YES
602	352	PHOENIX-WEST	YES	YES	YES	YES
602	415	PHOENIX-WEST	YES	YES	YES	YES
602	447	PHOENIX-WEST	YES	NO	YES	YES

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	484	PHOENIX-WEST	YES	YES	YES	YES
602	485	PIMA	NO			
602	476	PINE	NO			
602	502	PINNACLE PEAK	YES	NO	YES	NO
602	563	PINNACLE PEAK	YES	NO	YES	NO
602	585	PINNACLE PEAK	YES	NO	YES	NO
602	772	PRESCOTT EAST	NO			
602	775	PRESCOTT EAST	NO			
602	442	PRESCOTT MAIN	YES	NO	YES	NO
602	445	PRESCOTT MAIN	YES	NO	YES	NO
602	717	PRESCOTT MAIN	YES	NO	YES	NO
602	771	PRESCOTT MAIN	YES	NO	YES	NO
602	776	PRESCOTT MAIN	YES	NO	YES	NO
602	778	PRESCOTT MAIN	YES	NO	YES	NO
602	290	RINCON	NO			
602	296	RINCON	NO			
602	298	RINCON	NO			
602	721	RINCON	NO			
602	722	RINCON	NO			
602	733	RINCON	NO			
602	751	RINCON	NO			
602	885	RINCON	NO			
602	886	RINCON	NO			
602	471	RIO VERDE	NO			
602	348	SAFFORD	NO			
602	428	SAFFORD	NO			
602	720	SAINT DAVID	NO			
602	475	SAN CARLOS	NO			
602	688	SANDERS	NO			
602	385	SAN MANUEL	NO			
602	312	SCOTTSDALE	NO			
602	423	SCOTTSDALE	NO			
602	441	SCOTTSDALE	NO			
602	481	SCOTTSDALE	NO			
602	675	SCOTTSDALE	NO			
602	874	SCOTTSDALE	NO			
602	941	SCOTTSDALE	NO			
602	945	SCOTTSDALE	NO			
602	946	SCOTTSDALE	NO			
602	947	SCOTTSDALE	NO			
602	949	SCOTTSDALE	NO			
602	970	SCOTTSDALE	NO			
602	990	SCOTTSDALE	NO			
602	994	SCOTTSDALE	NO			
602	204	SEDONA-MAIN	YES	NO	YES	NO
602	282	SEDONA-MAIN	YES	NO	YES	NO

Arizona ISDN Single Line Service Availability
By Wire Center *(continued)*

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	284	SEDONA-SOUTH	NO			
602	301	SHEA	YES	NO	YES	YES
602	314	SHEA	YES	NO	YES	YES
602	391	SHEA	YES	NO	YES	YES
602	451	SHEA	YES	NO	YES	YES
602	614	SHEA	YES	NO	YES	YES
602	661	SHEA	YES	NO	YES	YES
602	860	SHEA	YES	NO	YES	YES
602	452	SIERRA VISTA-MN	YES	NO	NO	NO
602	458	SIERRA VISTA-MN	YES	NO	NO	NO
602	459	SIERRA VISTA-MN	YES	NO	NO	NO
602	515	SIERRA VISTA-MN	YES	NO	NO	NO
602	533	SIERRA VISTA-MN	YES	NO	NO	NO
602	538	SIERRA VISTA-MN	YES	NO	NO	NO
602	456	SIERRA VISTA NO	NO			
602	378	SIERRA VISTA SO	NO			
602	627	SOMERTON	NO			
602	424	STANFIELD	NO			
602	561	SUNRISE	YES	NO	YES	NO
602	566	SUNRISE	YES	NO	YES	NO
602	572	SUNRISE	YES	NO	YES	NO
602	689	SUPERIOR	NO			
602	671	SUPERSTITION-EAST	NO			
602	982	SUPERSTITION-EAST	NO			
602	983	SUPERSTITION-EAST	NO			
602	373	SUPERSTITION-MAIN	NO			
602	380	SUPERSTITION-MAIN	NO			
602	984	SUPERSTITION-MAIN	NO			
602	986	SUPERSTITION-MAIN	NO			
602	396	SUPERSTITION-WEST	NO			
602	641	SUPERSTITION-WEST	NO			
602	807	SUPERSTITION-WEST	NO			
602	830	SUPERSTITION-WEST	NO			
602	832	SUPERSTITION-WEST	NO			
602	854	SUPERSTITION-WEST	NO			
602	891	SUPERSTITION-WEST	NO			
602	924	SUPERSTITION-WEST	NO			
602	981	SUPERSTITION-WEST	NO			
602	985	SUPERSTITION-WEST	NO			
602	749	TANQUE VERDE	YES	NO	YES	NO
602	760	TANQUE VERDE	YES	NO	YES	NO
602	303	TEMPE-MAIN	YES	NO	NO	YES
602	350	TEMPE-MAIN	YES	NO	NO	YES
602	358	TEMPE-MAIN	YES	NO	NO	YES
602	693	TEMPE-MAIN	YES	NO	NO	YES
602	727	TEMPE-MAIN	YES	NO	NO	YES

Arizona ISDN Single Line Service Availability
By Wire Center (continued)

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	731	TEMPE-MAIN	YES	NO	NO	YES
602	784	TEMPE-MAIN	YES	NO	NO	YES
602	804	TEMPE-MAIN	YES	NO	NO	YES
602	829	TEMPE-MAIN	YES	NO	NO	YES
602	858	TEMPE-MAIN	YES	NO	NO	YES
602	894	TEMPE-MAIN	YES	NO	NO	YES
602	902	TEMPE-MAIN	YES	NO	NO	YES
602	921	TEMPE-MAIN	YES	NO	NO	YES
602	929	TEMPE-MAIN	YES	NO	NO	YES
602	965	TEMPE-MAIN	YES	NO	NO	YES
602	966	TEMPE-MAIN	YES	NO	NO	YES
602	967	TEMPE-MAIN	YES	NO	NO	YES
602	968	TEMPE-MAIN	YES	NO	NO	YES
602	345	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	413	TEMPE-MCCLINTOCK	YES	NO	YES	YES
602	491	TEMPE-MCCLINTOCK	YES	NO	YES	YES
602	730	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	752	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	756	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	777	TEMPE-MCCLINTOCK	YES	NO	YES	YES
602	820	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	831	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	838	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	839	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	897	TEMPE-MCCLINTOCK	YES	YES	YES	YES
602	443	THUNDERBIRD	YES	NO	YES	NO
602	483	THUNDERBIRD	YES	NO	YES	NO
602	596	THUNDERBIRD	YES	NO	YES	NO
602	905	THUNDERBIRD	YES	NO	YES	NO
602	922	THUNDERBIRD	YES	NO	YES	NO
602	948	THUNDERBIRD	YES	NO	YES	NO
602	951	THUNDERBIRD	YES	NO	YES	NO
602	991	THUNDERBIRD	YES	NO	YES	NO
602	998	THUNDERBIRD	YES	NO	YES	NO
602	907	TOLLESON	NO			
602	936	TOLLESON	NO			
602	457	TOMBSTONE	NO			
602	478	TONTO CREEK	NO			
602	398	TUBAC	NO			
602	318	TUCSON-EAST	NO			
602	321	TUCSON-EAST	NO			
602	322	TUCSON-EAST	NO			
602	323	TUCSON-EAST	NO			
602	324	TUCSON-EAST	NO			
602	325	TUCSON-EAST	NO			
602	326	TUCSON-EAST	NO			

Arizona ISDN Single Line Service Availability
By Wire Center *(continued)*

NPA	NXX	WIRE CENTER	NI	NUM CHG	64CCC	X75P
602	578	TUCSON SOUTHWEST	NO			
602	822	TUCSON SOUTHWEST	NO			
602	883	TUCSON SOUTHWEST	NO			
602	743	TUCSON WEST	NO			
602	647	VAIL NORTH	NO			
602	762	VAIL SOUTH	NO			
602	785	WELLTON	NO			
602	853	WHITE TANKS	NO			
602	463	WHITLOW	NO			
602	684	WICKENBURG	NO			
602	384	WILLCOX	NO			
602	422	WILLIAMS	NO			
602	635	WILLIAMS	NO			
602	289	WINSLOW	NO			
602	393	WINTERSBURG	NO			
602	427	YARNELL	NO			
602	687	YORK VALLEY	NO			
602	462	YOUNG	NO			
602	328	YUMA-MAIN	NO			
602	329	YUMA-MAIN	NO			
602	343	YUMA-MAIN	NO			
602	539	YUMA-MAIN	NO			
602	782	YUMA-MAIN	NO			
602	783	YUMA-MAIN	NO			
602	317	YUMA-SOUTHEAST	NO			
602	341	YUMA-SOUTHEAST	NO			
602	344	YUMA-SOUTHEAST	NO			
602	726	YUMA-SOUTHEAST	NO			
602	305	YUMA FORTUNA	NO			
602	342	YUMA FORTUNA	NO			
801	675	PAGE	NO			

USWEST® COMMUNICATIONS

GLOSSARY OF TERMS

ADUANAS	Mexican Secretariat of Communications and Transport
APCO-25	Digital radio standard by Association of Public-Safety Communication Officials
ATIS	Advanced Traveler Information System
ATMS	Advanced Travelers Management System
ATR	Automatic Traffic Recorder
AVC	Automatic Vehicle Count
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
BL	Backbone link communications circuit
bps	Bits per second
CCTV	Closed Circuit Television
Channel Bank	Telephone interface that digitizes and multiplexes voice signals
CO	Telephone Company Central Office
Codec	COder DECoder
Controller	Microprocess-based traffic control device
Cross-Connect	Telephone term for mechanical or electrical patch panel
CSU	Channel Service Unit (to communication channel)
CVO	Commercial Vehicle Operations
Digital Hierarchy	T1 Multiplexing hierarchy, defines standard bit rates
Digital Switch	CO or PBX that rapidly switches digital voice signals
DPS	Department of Public Safety
DS-n	Digital Signal number - designates a standard Time Division Multiplexed (TDM) circuit
DSU (see also CSU)	Digital Service Unit (to computer)
EIA	Electronics Industry Association
EPIC	Expedited Processing at International Crossings
FCC	Federal Communications Commission
FDA	Food and Drug Administration
FDM	Frequency Division Multiplexed
FMS	Freeway Management System
Gbps	1 Billion bits per second
GHz	Giga Hertz (1 billion Hertz)
HAR	Highway Advisory Radio
HELP	Heavy Vehicle Electronic License Plate
Hub	Equipment cabinet that terminates communication circuits
Hz	Hertz (cycles per second)
INS	Immigration and Naturalization Service
ISDN	Integrated Services Digital Network
ITS	Intelligent Transportation System

kbps	1000 bits per second
kHz	Kilo Hertz (1 thousand Hertz)
LAN	Local Area Network
LCD	Liquid Crystal Display
LL or DL	Local link communication circuit or Distribution link communications circuit
Mbps	1 Million bits per second
MHz	Mega Hertz (1 million Hertz)
MMFO	Multimode Fiber Optic
Modem	MOdulate DEModulate
MPEG	Motion Picture Expert Group - defines video compression standards for digital television
MVD	Motor Vehicle Division
NAFTA	North American Free Trade Agreement
NEMA	National Electrical Manufacturers Association
NTCIP	NEMA's National Transportation Control/ITS Communication Protocol
OC-n	(SONET) Optical Carrier level-n
PBX	Private Branch Exchange (Telephone)
Peer-to-Peer	Equal status communications protocol
Ramp Metering	Freeway ramp access control
RBDS	Radio Broadcast Data System
Refarming	Refers to redefining RF communications channels in mobile radio bands
RF	Radio Frequency
RWIS	Roadway Weather Information System
SCAN®	SSI, Inc.'s RWIS
SMFO	Single Mode Fiber Optics
SONET	Synchronous Optical Network
T1	Acronym for standard 1,544,000 bits per second T-Carrier digital circuit
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	Time Division Multiplexed
TOC	Traffic Operations Center
Trunked Radio	Controlled access radio circuits
TWP	Twisted Wire Pair
UHF Band	Ultra High Frequency RF Band
VHF Band	Very High Frequency RF Band
VMS	Variable Message Sign
WAN	Wide Area Network
WIM	Weigh-in-Motion