

# **Wireless Information Transmission Services for Intelligent Transportation Systems Applications**

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## **ABSTRACT**

Proliferation of Intelligent Transportation Systems (ITS) applications worldwide creates a continuously increasing demand for exchange of voice, data, and video information. This paper reviews and compares traditional wireless information exchange services and discusses their advantages and limitations for application within the ITS framework. In addition, emerging wireless communication technologies are presented together with an assessment of their potential capabilities towards enhancement of future ITS services and needs.

## **INTRODUCTION**

In the recent years Intelligent Transportation System (ITS) technologies have been widely deployed in Northern America to achieve a safe and efficient surface transportation system. Because almost every ITS user service requires some type of data communications support, the National ITS Architecture proposed the consideration of three separate and interconnected layers, namely Communication Layer, Transportation Layer and the Institutional Layer [1]. The aim of this action is to allow ITS communications requirements to catch up with the rapid development of modern communications technologies, especially in the field of wireless communications.

One of the most significant issues related to ITS communications today is the continuously growing need for data communications. Although existing wireline networks can serve ITS communications needs in most metropolitan and urban areas, the ITS system development in suburban and rural areas still depends on wireless communications services. Rapid deployment, easy configuration, and cost efficiency of such services may play a significant role in ITS success in non-urban settings.

Traditional wireless networks suffer from limitations in data transmission. The main reason is that most of these networks are primarily designed for voice delivery, with only few networks (e.g., ARDIS and RAM) designed purely for data transmission. Despite many recent improvements (such as the development of CDPD networks), most of the traditional wireless systems can not fully satisfy ITS communications requirements due to limited capacity/throughput, latency, connection stability, and coverage.

This paper focuses on the analysis of current ITS data service requirements and potential barriers. Current and emerging wireless data exchange technologies are reviewed, and their potential capability to enhance ITS services in the near future is discussed.

# **BASELINE ITS INFORMATION EXCHANGE SERVICES AND REQUIREMENTS**

## **Current Baseline ITS Information Exchange Services**

In current ITS applications, wireless technologies usually evolve through three types of approaches [18]:

- Taking advantage of existing (commercial or dedicated) communications systems (e.g., cellular radio, ESMR, SMR, etc.);
- Providing new services within current spectrum allocations by means of resource sharing (e.g., HAR radio, FM subcarriers); or
- Establishing dedicated systems with new spectrum, when current allocations are inadequate or new spectrum is required to meet growth demands (e.g., DSRC).

Typically, there are three types of information that need to be delivered in ITS applications, namely, voice, data, and video. Because of different signal features, voice, data, and video transmissions have different requirements. The main delivery needs of these three types of information are summarized in Table 1 [2][3].

In addition, there are two types of information delivery modes in communications systems, namely, circuit-switched and package-switched mode. In a circuit switched system, a specific communication link is established before the transmission and maintained during the transmission. This mode needs extra circuit set-up time with fixed transmission delay and is very suitable for long/real-time message transmission. On the other hand, in packet-switched networks, all data are grouped in packets and routed in the network to their destinations individually. This mode is suitable for burst or relative short message transmissions. The comparison of these two modes is summarized in Table 2 [2].

In current ITS applications, wireless data services have played a very important role. Table 3 summarizes current shared, dedicated, and existing commercial wireless resources that are involved in ITS data services.

## **CURRENT DATA TRANSMISSION OPERATIONAL BARRIERS AND FUTURE REQUIREMENTS**

Through the wide deployment of ITS functions, the requirement for data transmission kept on growing. Currently, available wireless data transmission services are incapable of fulfilling the following ITS communications requirements.

### Transmission of Image and Video Data

A communications requirement survey from the national public safety agencies illustrated

that transmission fingerprint image or living video will be highly desirable in the near future [10][11]. Also, emergency response agencies are very much interested in this function. For example, following a crash, the video showing on-site injuries could be transmitted remotely to the medical center and help the pre-evaluation of the crash severity and necessary actions.

There are several transmission modes for living video transmission. The most important consideration for proper mode selection is the transmission throughput, which depends on the desirable type of services needed. Table 4 provides the general description of communications needs for transmission of different types of video data.

With the exception of specifically designed dedicated spread spectrum or microwave radios, currently available wireless data communications systems cannot support image and video data transmission functions.

### Remote File/Database Accessing

Development of advanced traveler information services aims at allowing mobile users to use mobile wireless terminals to access Internet functions such as:

- In-vehicle e-mail and WWW browsing services;
- En-route yellow-page and traveler information inquiries;
- Digital map or real-time traffic network information; and
- Dynamic / integrated route guidance.

In addition, law enforcement and emergency response agencies started or plan to equip their patrol and service vehicles with on-board computers to enable remote database access ability.

Remote Internet support or database accessing functions create the need for wireless communications links that provide adequate throughput, real-time response, stable connections, as well as the minimum transmission delays.

### Data Broadcasting Capabilities

Besides voice-based commercial broadcasting, current data-based subcarrier systems for traffic information services are still limited in data capacity, coverage in rural areas, as well as nationwide interoperability.

### Coverage and Interoperability of Data Services

Many ITS services require nationwide coverage and system interoperability, but most of current terrestrial systems are only available in metropolitan and urban areas, because of demand and market penetration. This situation affects the effectiveness of seamless data collection in the rural areas, and the effective distribution of traffic information.

In summary, currently available ITS wireless information transmission services suffer limitations with respect to data capability, coverage, and interoperability. Thus, it becomes vital

for the success of ITS applications to investigate features and potential capabilities of developing communications technologies. This topic is discussed in detail next.

## **EMERGING INFORMATION EXCHANGE TECHNOLOGIES FOR ITS APPLICATIONS**

### **Improvement of Data Exchange Capability**

#### Enhanced Data Services in Digital Cellular Systems

Circuit-switched data services in first-generation analog cellular systems can no longer satisfy short, burst data transmission needs that are commonly met in ITS applications. CDPD, a digital data transmission technology overlaying the AMPS analog networks, can be used to merge this gap. Moreover, all deploying second-generation cellular systems are based on digital technology, which makes the data transmission more flexible.

Currently in the US, all three types of second-generation cellular systems (GSM, TDMA, and CDMA) have promised availability of data transmission services. GSM is the first digital cellular system that proposed abundant data services. Besides currently available Short Message Service (SMS) and circuit-switched 14.4 Kbps data service, High-Speed Circuit Switch Data (HSCSD) and General Package Radio Data (GPRS) will become available soon. Because of the inter connectivity with GSM, U.S. TDMA systems will fully support these data services and realize the inter-compatibility with GSM systems.

Moreover, the CDMA system also proposed several data services. The current circuit switched data for CDMA is also 14.4 Kbps, but will be expanded to 144 Kbps soon (1XRTT), as well as provide package services. Also, the currently tested High-speed Data Rate (HDR) service (which uses dedicated CDMA channel to deliver up to 1.8 Mbps data services) will be commercially available in the near future. The development tendency of the second-generation cellular systems is shown in Table 5.

#### Enhanced Data Services in LMR, SMR and ESMR Systems

Currently, most LMR, SMR and EMSR radio systems mainly support voice-based fleet dispatching services with very limited data capability (e.g., circuit-switched 4.8 Kbps). However, the wide deployment of AVL systems in transit, commercial vehicle and public safety fleet requires more stable and capable wireless data links between vehicles and dispatching center services. Most of currently used high frequency band SMR systems (e.g. 800/900 MHz) are based on digital trunked technology with the ability to support up to 64 Kbps data capacity. Enhanced data service will be available through these systems in the near future. For instance, Nextel, the largest ESMR in US, claims to offer circuit and packet switched data service at 9.6 Kbps through its iDEN networks [12].

On the other hand, low band LMR systems (below 400 MHz) will continue to offer a low

data capability because of a FCC rule, which will narrow the band width from 25 KHz to 6.25 KHz by the year 2005 [13].

### Enhanced Data Services in Data Networks

In the data-lonely networks, the CDPD is expected to continue to overlay the cellular systems and will merge with the advanced packet-based data service in the future. ARDIS/RAM packet-based data networks are expected to continue to increase their data capability from 8-19.2 Kbps presently to 28.8 Kbps [14].

## **New Generation of Services**

### The Third Generation Cellular Systems

The third generation (3G) cellular systems refer to currently developing next generation cellular technologies. The primary aim of 3G is global coverage for speech and low-to-medium bit rate services with the provision of high bit rate services over limited coverage area [15][16]. The future deployment of 3G systems is expected to benefit rural ITS wireless applications due to its powerful data capability. The design scenario for 3G system is shown in Table 6.

### Digital Radio and Satellite Broadcasting

Digital radio, known as Digital Audio Broadcasting (DAB), is a digital method of transmitting compact disc (CD) quality audio signals to radio receivers. In the US, DAB uses In-Band On-Channel (IBOC) broadcasting technology and takes advantages of current AM and FM stations to provide high quality digital audio services [17]. Moreover, the FM DAB is able to provide additional 64 Kbps data services depending on a particular station's interference environment, whereas the AM DAB also can provide additional 2.4 Kbps data services [18].

On the other hand, satellite-based audio broadcasting systems are currently under development. The satellite audio broadcasting system will use GEO satellites to deliver more than 100 channels directly to vehicle-embedded radios. Compared to conventional terrestrial-based broadcasting services (generally limited to distances of approximated 30 miles) the satellite audio system can provide much larger footprint (the size of US) and higher quality digital radio service (CD quality) [19][20][21].

The greatest benefit of broadcasting satellite systems for ITS applications is the good coverage of rural areas. When deployed, these systems are expected to provide the means for dissemination of traveler information services to remote locations.

### New Satellite Services

Currently available GEO satellite systems have limited data capabilities. There are at least two types of developing satellite systems that are expected to further enhance wireless data services.

## **Global Mobile Satellite Communication Systems**

Satellite systems that can provide mobile voice/data communication services were developed many years ago. The newly developed LEO/MEO system uses more complex satellite technologies and promises global mobile data/voice services in combination with terrestrial networks. These systems claim to provide services such as international roaming; rural telephone service; cellular fill-in services; commercial vehicle services, and maritime, aviation and government services. Most of these systems are capable of filling the telecommunication gaps of terrestrial coverage in remote rural areas.

## **Broadband Satellites Service (BSS) Systems**

Broadband Satellite Service (BSS) systems are intended to provide flexible capacity on demand for high-volume telephony, video conferencing, broadcast video, and high-speed Internet data services. Most of the BSS systems are still under development and will not be operational until the year 2001 at the earliest [14][22][23][19][24]. Broadband satellites appear ideal for serving future rural areas needs, including:

- Dedicated point-to-point connectivity;
- Alternatives of fiber-based backbone networks, and
- Fixed telephone (in rural areas).

Table 7 illustrates the potential data services of emerging satellite systems.

## **Nationwide Interoperability**

### Wireless Application Protocol

The Wireless Application Protocol (WAP) was designed to create a global wireless protocol specification that can work across all wireless technologies [22]. The recently launched new wireless Internet terminals, which are based on WAP, demonstrated the feasibility of interoperable terrestrial wireless networks.

### Statewide Multiple Agencies Wireless Network Deployment

Currently, more than 30 states in the U.S. are proposing or developing multiple agencies sharing statewide SMR systems. Most of these systems use advanced digital trunk radio technology to form a statewide wireless mobile communication network. This concept enhances the system efficiency and coordination capability, while satisfying different state agencies' specific service requirements.

## SUMMARY AND CONCLUSIONS

This paper looked at needs of ITS applications for information exchange services and potential options. In summary, current and developing wireless communications systems range from terrestrial high-speed services to satellite based future broadband services and provide a variety of options for current and future ITS data services requirements. Emerging technologies are expected to offer assistance to various ITS functions by providing:

- Enough data capacity for enabling slow moving or full motion video data transmission;
- Stable, speedy, and capable wireless data connection for remote data access and mobile Internet services;
- Full coverage for effective data collection at rural areas through satellite systems;
- Effective and efficient travel information services utilizing new terrestrial and satellite digital broadcasting systems; and
- Seamless ITS system coverage from urban to rural areas.

The final selection of appropriate technologies for implementation will depend on the technology maturity, availability, as well as the practical ITS requirements and needs.

## ENDNOTES

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**Table 1. General Transmission Features for Voice, Data and Video Communications [2][3]**

	Voice	Data	Video
Band width needed	Analog: 300-3400 Hz Digital: 4.8-32 Kbps	Digital: 500 bps – 11 Mbps	Analog: 5 MHz (TV) Slow moving scan: 300-500 Kbps Digital: 3-6Mbps (MPEG)
Transmission delay	Delay sensitive <100 ms Fixed end-to-end delay	Varied by needs Sec. - min.	Real-time transmission needs small delay.
Error rate	BER <10 <sup>-2</sup>	Uncoded BER <10 <sup>-5</sup>	Bit error sensitive; Uncoded BER <10 <sup>-6</sup>
Switched mode	Circuit-switched	Circuit-switched Packet-switched	Circuit-switched

**Table 2. Comparison of Circuit-switched and Packet-switched Modes [2]**

	Circuit Switched Mode	Package Switched Mode
Advantages	Continuous accessing; No latency or wait time during transmission.	Efficient usage of the frequency spectrum; High flexibility.
Disadvantages	Inefficient frequency usage; Susceptibility to dynamic changes in the communication channel; Inflexibility for mobility.	Packet delay; Packet drops; Network congestion; Latency.
Suitability	Voice, long length data (file), video	Data (burst message)
Charge method	By channel time	By transmission size

**Table 3. List of Current ITS Data Exchange Services**

Wireless System	Data Service Features	Current Application Situation
Paging system	One-way: 1.2 - 9.6 Kbps Two-way: 1.2 - 9.6 Kbps (forward), 300 - 600 bps (reverse)	43.5 million one-way pager users and 150,000 two-way pager users (1998) [4] <ul style="list-style-type: none"> <li>• Traffic information services</li> <li>• Fleet management (two-way paging)</li> </ul>
Cellular system PCS system	AMPS: CS 14.4 Kbps NAMPS: SMS GSM: SMS (160 chars); CS 9.6 -14.4 Kbps TDMA: SMS, CS 9.6 Kbps CDMA; SMS (256 chars), CS 14.4 Kbps	Cellular coverage: 90% US population, and 70% US land mass [5]. Digital PCS: approximate 29% of the total cellular coverage area or 20% of the US land mass [5]; Type of coverage: metropolitan areas; <ul style="list-style-type: none"> <li>• Traffic information services</li> <li>• Mayday / emergency services</li> <li>• Roadside smart call box</li> <li>• Communication links to roadside facilities</li> </ul>
CDPD	AMPS: PS 19.2 Kbps	More than half of the geographic US [6]; Type of coverage: Regional coverage <ul style="list-style-type: none"> <li>• Automatic vehicle location / fleet management</li> <li>• Law enforcement on-board remote data access</li> </ul>
Radio data networks	ARDIS: PS 4.8 - 19.2 Kbps RAM: PS 8 Kbps Metrocom: 28.8 Kbps, 128 Kbps (low mobility)	Covers 90% US business population; Type of coverage: urban areas [7] <ul style="list-style-type: none"> <li>• Fleet management</li> <li>• Traffic information services</li> </ul>
Telemetry	32 - 100 bits	100% of the total cellular coverage area [8] <ul style="list-style-type: none"> <li>• Cargo tracking / automated vehicle location</li> </ul>
ESMR system	9.6 Kbps	Regional service available <ul style="list-style-type: none"> <li>• Fleet dispatching / management</li> </ul>
Satellite communications	GEO: 2.4 Kbps - 9.6 Kbps PCS: N/A; LLEO: 0.6 -9.6 Kbps	<ul style="list-style-type: none"> <li>• Commercial vehicles fleet management;</li> <li>• Remote monitoring (operational test)</li> </ul>
Low speed AM & FM RBDS	1.2 Kbps	Covers 90% CA & US population (CUE network)[9] <ul style="list-style-type: none"> <li>• Traffic information services</li> <li>• DGPS broadcast services</li> </ul>
High speed FM subcarriers	HSDS: 19 Kbps DARC: 16 Kbps STIC: 18.8 Kbps	Covers 90% CA & US population (DARC: CUE network)[9] <ul style="list-style-type: none"> <li>• Traffic information services</li> </ul>
Highway maintenance radio (LMR)	CS 1.2 - 9.6 Kbps	Type of Coverage: local coverage <ul style="list-style-type: none"> <li>• Remote site data collection / control</li> </ul>
220 MHz	14.4 Kbps	<ul style="list-style-type: none"> <li>• Traffic advisory service (operational test)</li> </ul>
SMR trunked systems	CS 4.8 - 9.6 Kbps	<ul style="list-style-type: none"> <li>• Transit wireless communications systems</li> <li>• Public safety wireless communications systems</li> <li>• Commercial fleet management</li> <li>• Automated vehicle location / fleet management</li> </ul>
Spread spectrum radio	1.2 Kbps - 2 Mbps	<ul style="list-style-type: none"> <li>• Remote traffic controller data communications</li> </ul>
Dedicated short range communications	500 Kbps (forward) 250 Kbps (reversed)	<ul style="list-style-type: none"> <li>• Electronic toll collection</li> <li>• Automated vehicle identification</li> </ul>
Microwave systems	1.5 Mbps - 155Mbps	<ul style="list-style-type: none"> <li>• Alternatives of wireline backbone</li> </ul>
Meteor burst systems	PS 9.6 Kbps	<ul style="list-style-type: none"> <li>• Remote monitoring / data collection</li> </ul>

CS – Circuit Switched; PS – Packet Switched; SMS – Short Message Service.

**Table 4. Video Transmission Requirements**

Video Mode	Features	Bandwidth / throughput needs
Full motion analog video color	Analog, 30 frame /s (700 X 525)	4.2 MHz, 201 Mbps
Full motion analog video	Analog, 30 frame /s (700 X 525)	4.2 MHz, 67.2 Mbps
Frizzed / slow scan video	Analog, 3-15 frame /s (256 X240)	56 – 384 –768 Kbps
Digital compression video	Digital MPEG	1.544 Mbps

**Table 5. Data Transmission Services in Second Generation Cellular Systems**

2nd Generation Cellular Systems	Data Service	
	Short Term	Long Term
GSM / TDMA	CS & PS 38.4 Kbps; 76.8 Kbps HSCSD (2000) 14-155 Kbps GPRS (2000)	Evolving to 3G system; 384 Kbps EDGE
CDMA	Keep deployment in urban areas Compatible with satellite systems CS & PS 9.6 to 64 Kbps Dedicated HDR 1.8 Mbps First phase of CDMA2000 (1XRTT 144 Kbps)	Evolving to 3G system; 3XRTT data up to 2 Mbps
CDPD	Overlay on digital cellular systems (up to 64 Kbps) Merging with digital data packet services	Merging with 3G packet data services

**Table 6. 3G Data Services Scenario [15][16]**

	Real Time	Constant Delay	Non real Time	Variable Delay
Operating environment	Peak bit rate	BER / max. Transfer delay	Peak bit rate	BER/ max. Transfer delay
Rural outdoor (terminal speed up to 250 km/h)	At least 144 Kbps (preferably 384 Kbps) Granularity appr. 16 Kbps	delay 20-300 ms BER $10^{-3} - 10^{-7}$	at least 144 Kbps (preferably 384 Kbps)	BER $10^{-5} - 10^{-8}$ Max transfer delay 150 ms or more
Urban /Suburban outdoor (terminal speed up to 150 km/h)	At least 384 Kbps (preferably 512 Kbps) Granularity appr. 40 Kbps	delay 20-300 ms BER $10^{-3} - 10^{-7}$	at least 384 Kbps (preferably 512 Kbps)	BER $10^{-5} - 10^{-8}$ Max transfer delay 150 ms or more
Indoor/ Low range outdoor (Terminal speed up to 10 km/h)	2 Mbps Granularity appr. 200 Kbps	delay 20-300 ms BER $10^{-3} - 10^{-7}$	2 Mbps	BER $10^{-5} - 10^{-8}$ Max transfer delay 150 ms or more

**Table 7. Data Capability of Developing Satellite Systems**

Satellite Systems	Current Situation	Near term	Long term
Satellite – PCS	Global coverage Under development or deployment Digital voice / data	Compatible with terrestrial systems Continued deployment Data capability (2.4 – 38.4 Kbps) Lower service charge	Full deployment
Satellite – data only	Under deployment Store-forward system Regional service Data 0.6-9.6 Kbps Medium maturity	Full deployment (2000+) High speed data 1.93 – 50 Kbps Lower service charge	Increased data capabilities
Satellite broadband	Under development Broadband system Low maturity	Start of deployment (2001+) 16 Kbps – 5 Mbps – 155 Mbps data Global coverage	Full deployment

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