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Prospective of Technology Advances in Intelligent Transport System tying transportation and telecommunication worlds together

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Abstract

Throughout the world in major urban centers, the volume of vehicular traffic on roads continues to increase. ITS provides drivers with traffic information and new routing options en route in order to make them move quickly to their destinations. The higher mobility, the more productivity we gain. The ultimate goal of Intelligent Transport System is to improve mobility. ITS world is broad and quite varied, as demonstrated by ITS user services, their distinct needs, and complex interactions and synergies. ITS ties the transportation and telecommunication worlds together. The complex world of telecommunications is evolving and expanding rapidly. Especially over the last two decades, the birth and unprecedented growth of wireless is really marvelous and further holds tremendous promise into the future. This wireless and emerging technologies will offer extensive opportunities to handle many ITS user services, and alter many of the traditional paradigms of transportation.

I. Introduction

Nobody can see 400 meters ahead situation on roads in driving. Drivers rush instinctually into their best route even if the road is already congested. This in result makes the congestion getting worse and worse. It is because of the lack of information. Intelligent Transport System (ITS) delivers lots of tailored and real-time traffic information to drivers such that they can choose the best route to their destinations. This offers a new paradigm, for the future transport schemes, to make use drivers intelligence in the traffic control. Thus, in the 21st century, to receive the up-to-second traffic information, some 40% of vehicles on the roads will have at least basic on-board ITS instrumentation that provides good linkage with the infrastructure information sources. Drivers also benefit from intelligent cruise control, congestion free, and other safety and convenience enhancements. Fully automated highway operation will be even possible. Travelers have reaped the benefits of these solutions as they utilize the seamless travel services provided across the country. The result has been the proliferation of improved traffic management techniques, advanced information technologies, driver aids, and vehicle safety enhancements.

Of this ITS function clearly comes out the pivotal activity of communications to 21st century transportation. No technology has taken a greater role in defining the transportation systems in the future than the revolution in data communications. Just as the nature of day-to-day life has been affected at home and at business by ubiquitous and inexpensive data communications, so also has the experience of travel, from the response to emergencies to restaurant reservations. People no longer arrive at traffic jams unaware of the current conditions. They now have the information that may lead them to use transit or seek alternate routes to avoid congestion. And the use of multiple transit modes for a trip is no longer an inconvenient or confusing option. Only information can reduce the uncertainty and this reduced uncertainty has made travel more pleasant for all. How has this occurred? Through a combination of infrastructure and services, provided by both the public and private sectors. The infrastructure is used primarily to support the wireline and wireless communication of real-time data. This has, in turn, enabled services that provide useful information to travelers to help them make intelligent travel decisions.

The traveler receives a level of transportation service via commercial entities, in the form of Information Service Providers (ISPs). These ISPs provide value-added services, by collecting data from various sources and creating valuable information products and services that consumers now see as just as necessary as their TV, on-line computer, and telephone services. ISPs have arisen in many markets : some run the general communications infrastructure, some serve the personal needs of the traveling public, and some serve special markets like the freight operators.

For personal travel, each ISP travel customer has a User Profile which comprises characteristics of both the user and the vehicles they operate. The following shows an example of such a profile for a private vehicle traveler :

- o On board instrumentation
  - On-board computing
  - On-board databases : digitized maps
  - Communication capability
  - User interfaces : voice, display
  - Driver-aid equipment available on-board : adaptive cruise control
- o Personal characteristics
  - Regular travel destinations
  - Route type preference : highway versus side streets
  - Preferred user interfaces
  - Information needs
  - Pay-for-service subscriptions

Before setting out on a trip, users may modify their profile and alter the trip plan according to recommendations from the ISP. This information is available at home, at the office, at public kiosks, using the personal digital assistants (PDAs) first introduced in the 1990s, or on-board the vehicle. Where desired, ISPs coordinate multiple customers to create ride-sharing opportunities when needed.

II. Communications

The developments in portable wireless devices and data communications have been, in many ways, the key enabling technology in ITS for the traveling public. For the individual traveler, hand-held and in-vehicle devices can support myriad traveler information services throughout the country. The majority of the populace has access to these services using equipment that works with Short Messaging, Mobile Cellular and Low-Earth Orbit(LEO) satellite systems to ensure that traveler services are available everywhere at all times.

Though the traveler mass market has embraced the short messaging, mobile cellular and satellite-based data standards, other markets exist in specialized standards that are particularly appropriate to certain situations. Beacon-based communications, typically using short range Gigahertz frequency radio transmissions, are in widespread use for dedicated short range communications needs. These systems support electronic toll collection, commercial vehicle clearance, parking payment, in-vehicle signing, and a host of other applications.

1. Technologies for ITS applications

The ITS Architecture provides the framework that ties the transportation and telecommunication worlds together to enable the development and effective implementation of the broad range of ITS user services. Four communication media types are recognized to support the nineteen ITS subsystems. They are wireline(fixed-to-fixed), wide area wireless (vehicle-to-wireline), dedicated short range wireless(vehicle -to-roadside), and vehicle-to-vehicle communications.

The Center Subsystems are tied together over a wireline network. Wireline network options include Ethernet, Fiber Distributed Data Interface(FDDI), Synchronous Optical NETwork(SONET), and Asynchronous Transfer Mode(ATM) network, leased lines, Frame Relay(FR), Integrated Services Digital Network(ISDN), Metropolitan Area Network (MAN), Wide Area Network(WAN), Internet, and Switched Multimegabit Data Service (SMDS).

Wide area wireless technologies include Global System for Mobile Communications(GSM), SMR, Enhanced Special Mobile Radio(ESMR), PCS, ARDIS, RAM, Geotek, 220 MHz, Metricom, Tetherless, two-way paging, and Cellular Digital Packet Data(CDPD). A large data flows are best supported by commercially available mobile wireless data networks operated in the packet switching mode. Prominent among these today are GSM, RAM, ARDIS, and CDPD. CDPD have the delay from the vehicle to the infrastructure, even in the presence of non-ITS data, and with an incident during the peak period, is very low(150 ms for ITS only;300 ms for ITS plus non-ITS;10% increase in the sectors affected by the incident). Shortly, Short Messaging Service(SMS) using personal Air Communications Technology(pACT) and/or inFLEXion protocols and Cellular Digital Packet Data(CDPD) service will provide the base for an affordable wireless data communications capability. Mobile workers have been the first to use these technologies. The price of SMS is almost same as that of the existing alpha-numeric radio pager but its speed is one hundred times higher, and CDPD data phone has also begun to drop rapidly, as they become a commodity item like cellular phones. Technology is still advancing : hot on the heels of CDPD are new personal communications systems(PCS) digital standards and will be immediately followed by Future Public Land Mobile Telecommunications System(FPLMTS).

There are an array of satellite systems that are suitable for ITS applications. These include a variety of Little(data only) and Big(voice and data) low-earth-orbit(LEO) systems, as well as more conventional medium-earth-orbit(MEO) and geosynchronous orbit(GEO) systems. Many of these systems are not yet deployed, however they are projected to be in service within the next few years. Because of the higher costs for services and equipment, satellite systems would be most appropriately used where terrestrial alternatives are not available. Among the satellite systems, little LEO choices seem to be the most appropriate, since they are targeted specifically at short bursty data transactions. Emerging satellite communication technologies are ORBCOMM, STARSYS, VITASAT, MSAT, Constellation, GLOBALSTAR, IRIDIUM, TELEDESIC, Ellipso, Odyssey, Skycell, VSAT, and OmniTRACS. Cost of the service and terminals are common issues to be a viable candidate for ITS user services.

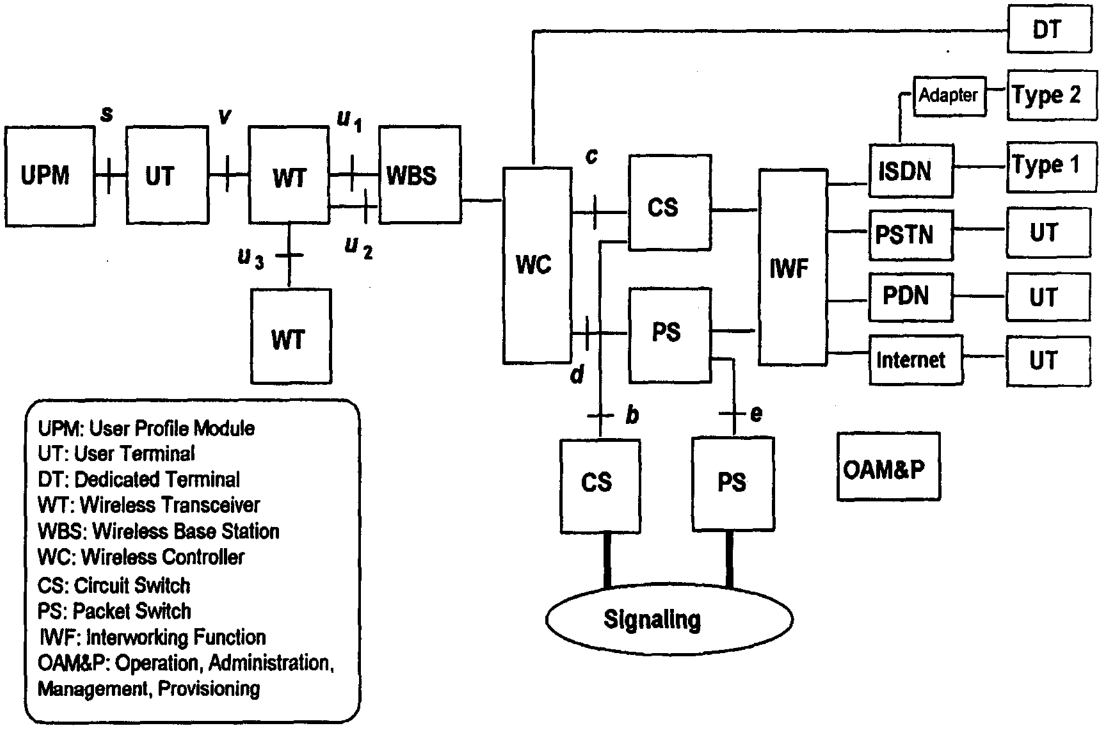
There are several broadcast media choices for one-way ITS communications. The most prominent among these are FM Subcarrier systems. In 1955, the FCC authorized FM radio stations to add one or more subcarriers onto the main carrier of their broadcast FM channels, and updated in the early 1980s to expand the subcarrier technologies which could be used. Now, subcarriers use the 53-99 kHz band of the channel to send additional information. Three leading subcarrier systems of HSDS, DARC, and STIC have nominal 16 kbps data rate, and RBDS FM subcarrier 1.2 kbps. They could be used in the small data ITS application.

The short range wireless is concerned with information transfer of a localized interest. There are two types of short range wireless communications : vehicle-to-vehicle and Dedicated Short Range Communications (DSRC). Vehicle-to-vehicle wireless support the Automated Highway System(AHS) and intersection collision avoidance implementations. Up to 20 Mbps data rate of wireless LAN and over 200 kbps beacon technologies can be easily fused into the DSRC applications. 70 GHz sub millimeter wave technology has been under development for the high reliable and high speed vehicle-to-vehicle data applications.

Service prices for two-way systems have come down in recent years, however, cost is a significant issue for the consumer, both for the communications device and the charges for service. If equipment costs were to drop to the 200 range, and more applications were to become available, a mass market could develop. This will probably take a few years. ITS is no different in this respect than other wireless data application areas. ITS applications will benefit from the developments and user acceptance trends in the broader fields of the mobile office and wireless Internet access.

2. ITS Network Reference Model

The network reference model for ITS provides an architecture or structure that shows how various communication technologies can im-



plement the Architecture Interconnect Diagrams developed in the next section, and is a generic abstraction which builds upon several reference models developed for standard commercial systems. Boxes represent the physical equipment. The interfaces important to ITS are identified by lowercase letters(s, v, u1, u2, u3). s signifies a plug-in, smart card interface. v signifies any kind of wireline connection(for instance, RS-232) or even a bus if the UT and WT are integrated.

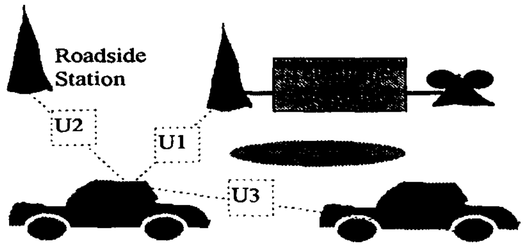
The wireless portion consists of the User Profile Module(UPM), the User Terminal(UT), the Wireless Transceiver(WT) and the Wireless Base Station(WBS). The connections through the Dedicated Terminal and various User Terminals are shown in the column of boxes on the right. The equipment in the center is the existing public telecommunications services.

3. Air link interfaces

The ITS network comprises of standard commercial systems including PCS, GSM or DCS-1800, TIA-IS-41, CDPD, Intelligent Network (IN)..., and satisfies the ITS user's needs by the identified communication services through wireline and wireless interfaces.

Communication services are identified three types with Conversational services, Messaging services, and Distribution services. Conversational services provide the real-time response for a user within a second or less. Messaging services are like a computer e-mail. Distribution services may be either broadcast or multicast. Broadcast messages are sent to all users while multicast messages only to a subset of users.

The most important reference point is the wireless interface connecting the wireless base station and the wireless transceiver. The wireless connections are defined by U links. To meet most



of the communication element's objectives, as well as those of the overall architecture, it is imperative that the air interface become standard. The wireless portion of the architecture is manifested in 3 different ways. Therefore, the U interface is realized in three ways : U 1, U 2, U 3, with each interface corresponding to one of the wireless manifestations, as defined :

◇ Vehicle-to-Wireline Connection(U1) : Conversational, Messaging, Multicast

U1 defines the wide-area air link to one of a set of base stations providing connections between mobile ITS users or mobile and wireline users. It is typified by the current cellular mobile networks or the larger cells of Specialized Mobile Radio, etc., for two-way communication, and FM subcarrier or paging networks for one-way communication. U1 link provides multiple functions necessary to deliver data to a mobile user from a wireline user, or reversibly. Because the wireline users already have their own legacy protocols and interfaces, establishing the best path may depend on how to keep compatibility with the legacies. In those locations ITS users may deploy their own dedicated system. Exactly, U1 interfaces the mobile to the first base station. U1 link will evolve its capability from the current CDPD, PDA, SMS, and nPCS air interface to the next coming broadband PCS, and FPLMTS standards. SMS has relatively strong points of its small size, wide coverage, and high rates of 115 kbps data speed.

◇ Vehicle-to-Roadside Connection(U2) : Conversational, Messaging, Broadcast

U2 defines the short-range air link used for close-proximity(typically, less than 50100 feet) transmissions between a mobile user and a base station, as occurs when a vehicle user communicates with a toll booth, a parking lot booth, or the reception of information from roadside transmitters(roadside sign information). The primary use for this link is for rapid query-response interchanges and for local broadcast of information to nearby vehicle users. The interchange must take place quickly as the vehicle will need the response for subsequent action, and the isolation of various users from jamming each other is based on range between user and base station, more than different frequencies. Wireless Local Area Network (wLAN) technology may be a ripe candidate. wLAN in 17 Giga hertz has a data transport capability of over 20 Mbps.

◇ Vehicle-to-Vehicle Connection(U3) : Conversational, Messaging, Broadcast

U3 addresses the vehicle to vehicle air link used for the intelligent cruise control, reducing headway, platooning drives, lane keeping, radar brakes, collision avoidance and so forth, as occurs in implementing the Automated Highway System(AHS). U3 link includes no base station and no immediacy in the path. U3 link provides high data rate, burst, usually line-of-sight transmission with high reliability between vehicles. This is still an area of research and standards for this link are in their infancy. Experimental systems use 70 Giga hertz frequency band.

4. Data Privacy and Security

The increase in wireless data transfer and the realization of the probable future scale of these services has raised legal concerns. Most notably, privacy and data security issues are often cited. The American Federal Information Processing Standard(FIPS) approved in 1994 defined the standard for inexpensive encryption hardware that is now becoming commonly available. Digital cellular phone technology is also becoming more widely available. The Code Division Multiple Access(CDMA) standard for digital cellular(as well as satellite wireless) has proven very resistant to electronic eavesdropping. The upshot is that technology will clearly be available and affordable, when needed, to protect the privacy of data transmission.

5. Information Service Providers

The ISPs, some publicly run and some private, are typically physically located wherever is most cost effective. Some provide their services from remote locations, while others are located right at the roadside. Typically, the remotely located ISPs provide trip planning, traveler information, electronic yellow pages, and other functions. The ISPs that are physically located near the roadside, right at the place where their services are accessed, transact vehicle or traveler electronic payments, manage modern parking facilities with reservation capabilities, and other similar functions.

The true equity of ITS becomes apparent in the partnership between the public ITS infrastructure providers and the private sector ISPs. This mix of public and private efforts has led to the rapid expansion of new services, while at the same time ensuring that everyone has access to basic transportation information. We see the ISPs creating services that cater to the needs of specific groups of users. And together we see a public-private partnership based on the exchange of information that enhances the success of both the public agencies and the private ISPs.

The wide acceptance of ITS technologies and the proliferation of ISP-based services has seen some ITS technologies merge with other broader markets. Old tag devices usable for toll fees, needed to be replenished or replaced when exhausted, have given way to universal payment media that have many uses beyond ITS. Functioning like credit or debit cards, these payment devices have also enabled ISPs that once provided only ITS-based route planning to now provide many new services.

III. In-Vehicle Systems

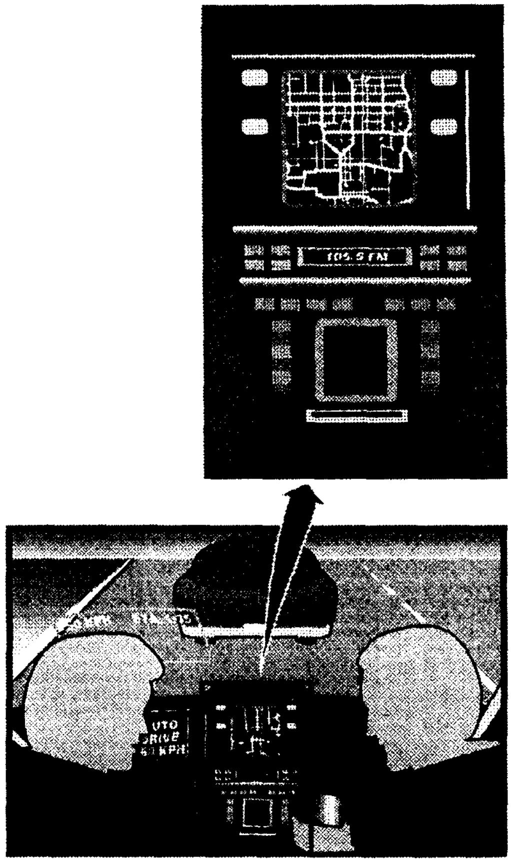
The driver support systems in typical private vehicles become increasingly sophisticated in the future. Cars right off the showroom floor sport wireless digital communications and centralized driver information systems. Some vehicles will have an in-vehicle system of navigational or route guidance instrumentation, which allows drivers to accurately determine their locations, and to select the best way to their destinations. Though the vehicles have become more complex, using them has become easier throughout the human factors engineering, including head-up displays and audio for eyes-on-road presentation technologies.

1. Route Guidance and Digital Maps

Digital navigation maps are core elements to support trip planning and navigation, to support signal controls, to perform planning studies and on and on. Many countries takes a more proactive solution rather than leaving the evolution of these maps completely to market forces. Once standards for the exchange of digital map data and attributes has been developed, digital map vendors will have flexibility in how they encode links, while map users can buy digital maps for their products and systems confident that they will not be locked into a single provider or be unable to send or receive map data when needed.

Autonomous navigation systems for vehicles utilizing the technology of Global Positioning System(GPS) becomes a de facto standards. The current positioning accuracy in the GPS system is about 100 meters, but with the establishment of a communications channel to the vehicle, additional information can be provided which enhances the operation of the navigation system. Differential GPS(DGPS) corrections is one of the methods. DGPS compensates for local inaccuracies in the GPS system and are capable of providing positioning accuracy to less than one meter. The area of relevance for DGPS corrections is roughly the same as the communications coverage area. DGPS information can be delivered over FM broadcast, cellular mobile and paging networks. The operation of stand alone system has gone. From now is the age of networking and information sharing.

Though many of the mobile vehicle/traveler navigation units are still autonomous, consumers are increasingly looking forward the showup of a digital map. At this point, three different route guidance technologies exist. The first to appear were the fully autonomous units that required no communications. These units perform all their route computations locally using static navigation data. The local databases have evolved in sophistication to contain information about historical congestion patterns, and can use the day and time of travel to improve their



routing plans.

The second type of route guidance technology adds limited communications capability to the fully autonomous units. Using broadcast or point-to-point communications technology, significant exceptions to the expected traffic conditions are communicated by ISPs to the in-vehicle systems. These local systems then determine their routes autonomously, as before, but with better data.

The third type of route guidance technology moves the navigable route database and the route planning process out of the vehicle and into the infrastructure. The in-vehicle part of the system handles reporting vehicle motion or probe data, two-way communications, and the interface to the driver. PCS, PDA, SMS and mobile data phone are capable of two-way interactive communications. The subscribers to these services gladly provide the probe data; in exchange they receive personalized real-time guidance and travel mode options while en route, and personal security as a benefit of disclosing their location. Routing plans are provided by ISPs, who pool vehicle probe data, TMC information, and all other available inputs to provide real-time optimal routing. In all cases, encryption protects the privacy and security of the communications between the ISP and the traveler.

These latter two types of dynamic route guidance are of interest to commuters and local residents, as well as to visitors. Convenient real-time information about commonly traveled routes helps drivers make better pretrip decisions, picking the appropriate time to leave for work or shopping, and the best route for the trip.

All three route guidance technologies are currently available, and consumers can select whichever they prefer. All offer improvements over naive guidance without even historical data. The first two types of units autonomous nature, though, makes coordinated routing difficult. But the last can do. Better than 10% market penetration of ITS equipment is seen in consumer vehicles. With more ITS-equipped vehicles on the road, the operators of driver information and advisory services have been able to collect enough useful information about traffic conditions from their customers vehicles, acting as probes, to be able to provide timely and accurate dynamic guidance.

Access to these real-time services, plus the lower in-vehicle cost of the units that receive routes from the infrastructure, has made these route guidance systems increasingly popular.

2. Vehicle Transponder Tags

The use of toll-tags for automated toll collection has become increasingly widespread on tollways. It contributes not only to ease congestion at toll plazas but also allow commuters and commercial users to pay tolls while in motion. Point congestion problems associated with tolling have also been significantly improved in a very cost effective manner. To accomplish this automated fee collection, most systems use tags that that are linked to an account with a positive cash balance. There is also a strong movement to try to merge toll-tag technology with other payment media, to allow broader use in purchases with a universal proximity read card.

Commercial vehicle processing also can use the toll-tag technology. In this case the primary purpose is to identify vehicles for tracking through weigh-in-motion and automated electronic clearance systems. This technology is in its infancy, but large commercial vehicle operators are ready to start supplying electronic documentation.

These efforts to speed vehicles past toll booths and weigh stations have been applauded by drivers, and long standing congestion problems have even been solved. The use of tags for automated vehicle identification(AVI) is clearly on track to support many future ITS services like parking payment and even in-vehicle signage.

3. Vehicle Safety Systems

There has been yet another significant improvement in road transportation in the last few years. Sophisticated driver-aids, such as radar with head-up presentations of warnings, will be introduced in many vehicles, helping drivers avoid collisions and other accidents.

Some intelligent cruise control has already been debuted, adding headway detection to traditional cruise control, such that the system automatically tries to maintain safe stopping distances. These technologies are expected to significantly reduce accidents, particularly rear-end collisions in poor visibility conditions. For the near future, automated lane-keeping technology is also nearing deployment readiness in the research and development labs.

Commercial vehicles have seen even more innovations that reflect their special needs. Continual monitoring of on-board systems and loads is now possible through sensors. The results are displayed using intelligent interfaces that reduce driver distractions. In some cases, this information is even made available via wireless communications to the fleet management center. In addition, on-board electronic logs for both trucks and trailers help the drivers and fleet managers track proper procedures and preventative maintenance requirements.

With the key standards in place, and many of the public infrastructure upgrades done, the long predicted private market is emerging with force. The future gains in transportation efficiency and safety can only increase, as more and more options open to transportation providers and consumers.

IV. ITS Services and Applications

Public and private Information Service Providers carries out a key role in making the ITS dream a reality. Much of the required infrastructure development has been financed by private for-profit and not-for-profit ventures. Besides creating an array of value-added services that make transportation better, the ISPs also have proven to be the critical link necessary to realize many services. Most industries, recognizing the consumer market for travel services, are interested in the commercial ISPs to provide ITS-defined services. First ISPs may provide en route guidance to travelers, using SMR, cellular, or beacon technologies. These ISPs gather probe data from their guided customers, which they use to update travel time estimates.

1. Public Transit

Public transit has benefited greatly from the modernization impetus of ITS. The new generation of buses that support standardized data interfaces and safety enhancements is now widely deployed on urban streets. These new vehicles support information kiosk and communications systems to help travelers make the most effective use of their ride time. Transit management centers also support kiosks at remote locations that provide up-to-the-minute transit information to travelers.

The general trend has been towards integration and flexibility. Paratransit, ride sharing, parataxi, and other flexible route options all have bus and train schedule and parking data readily available to them either directly from transit agencies, or via ISPs and general media dissemination. The buses and passenger rail services are fully coordinated with each other, and all systems use a common fare media. A passenger can pay for an entire trip and use a single proximity sensed fare card for all modes. Besides the convenience, the selection of the entire multimodal trip allows continuous adjustments to be performed to ensure successful connections.

Special bus lanes are still in use, but they have been supplemented by sophisticated signal adjustment and priority schemes. Based on a buss performance relative to schedule and the vehicles planned route, plus the destinations and connection requirements of the passengers, traffic signal timing can accommodate the schedule needs. In some areas, flexible public transportation schedules, in response to service requests, are also now possible through the combination of automated vehicle location (AVL), communications, and adaptive scheduling provided by ITS. The nature of public transit has become more complex as a blend of public and private suppliers has evolved. Paratransit requirements and intra-suburban commuting have created many niche opportunities for private enterprise. ISPs now provide many trip planning and coordination services. These ISP functions have made the public transportation experience simpler, more available, and more convenient for the consumer.

2. Commercial Vehicles

Commercial vehicle operators are now inextricably linked with water, air, and rail freight transportation modes. Independent of ITS, tight interaction has evolved for intermodal freight. The ITS infrastructure has accommodated this technology and provided enablers for much of the roadway portion. The overall result has been a steady progression of increasing efficiency in freight operations.

In addition, the freight handling industry serves many critical needs where efforts trim costs and increase efficiency. Truck weight can be measured at mainline speeds by both roadside checking stations and properly equipped mobile inspectors. The biggest roadside change is not even visible to the eye...it is the adoption of uniform electronic data interchange(EDI, based on the earlier ANSI X12 and EDIFACT standards) protocols for all aspects of commercial and regulatory data and monetary transactions. Route plans, required regulatory clearances, fuel and registration fee payments, and all other record keeping and financial transactions are provided electronically from fleet management centers, or contracted ISPs, to the appropriate roadside stations and to government agencies, as needed.

Accompanying the wireless communications technology deployments is an equally profound increase in wide area network(WAN) infrastructure. High speed broadband services using optical fiber, synchronous optical network (SONET), and asynchronous transfer mode (ATM) have been deployed connecting all urban and inter-urban areas as part of the evolution of the National Information Infrastructure (NII).

3. Incident and Emergency Management

There have already been substantial improvements in traffic control technology. A number of the large metropolitan areas have begun to implement sophisticated adaptive traffic control systems backed by extensive sensor deployment. Major metropolitan areas have regional incident management programs, with plans for full instrumentation of area highways for automated incident detection and management.

The common surveillance technologies, like closed circuit TV cameras and roadway detector loops became now popular. Variable message signs, highway advisory radio, and the TV and radio media reach the majority of vehicles and ensure that everyone receives some improvement in real-time services. This is the beginning; we are realizing the major goal of ensuring that everyone receives benefits from

ITS.

Incident management and emergency services are related areas that have benefited greatly by advances in technology and in the deployment of infrastructure, particularly for communications.

The private caller on a cellular phone is the most effective detection mechanism, and automated systems can detect and verify incidents using probe data much more rapidly and at lower public sector cost than with loops or closed-circuit television(CCTV) alone. On-board Mayday systems automatically transmit identity and location when a serious collision occurs or a panic button is pressed, providing direct incident detection by the involved vehicles.

Emergency management services have seen the early experiments in signal preemption grow to maturity in the future. The improvements in the detection of emergencies and the response have saved many lives, yielding one of ITSs biggest successes.

4. Automated Highway System

Around in the year 2010s, vehicles will go under automatic control on some urban and inter-urban highways. Automated control of vehicles can create dramatically greater highway capacity, by reducing the space or headway between vehicles, under a strict protocol that guarantees safety. The vehicles revert to manual control as they prepare to exit the highway. The Automated Highway System(AHS) implies some key deployments of safety and convenience technologies like intelligent cruise control, collision avoidance, and lane keeping systems laid the groundwork for AHS. Adding vehicle-to-vehicle communications to support platooning and the basic roadway infrastructure to support AHS has put in place the final pieces. This recently deployed AHS capability allows vehicles to travel faster and more safely, even with very small headways between the vehicles. Part of the beauty of the system is that much of the in-vehicle equipment necessary to use the AHS can still be used when not in the AHS, to provide advanced safety features. We have seen improvements through ITS in safety, transport capacity, emissions, consumption of resources, productivity, and personal mobility. These gains have benefited the nation and enhanced the quality of life of the people.

V. Conclusion : What technologies from Here?

ITS has directed at revolutions of the transport system in the 21st century through a handshaking with communication technologies. ITS has set goals, explicitly or implicitly, in order to achieve improved safety, increased efficiency, reduced energy and environmental impact, enhanced productivity, and enhanced mobility. These are key drivers for raising industrial productivity and competitiveness, and improving the quality of personal life.

While pre-ITS transportation advances have often come from a single decisive stroke of technology, the nature of ITS has been different. It keeps rolling strategies and targets. The cooperative changes in transportation and communications technology have made the world a smaller place. The new revolution is in continuously tuning the system to most efficiently meet changing needs.

What has become clear is that the prosperity of the nation requires an efficient social transport system across every corner of the country. The first twenty years will create the technology and the infrastructure to improve the roadway transport system. The next twenty years will promise many things. The roadway transport improvements will march onward. Vehicle safety technology will continue its advances. Ways will be found to preserve and even increase personal mobility, in the face of increased population and decreased resources. Proudly, ITS technologies, the new alliance of transportation and communications, will open a splendid vision to the coming future, as have the combination of computer and communications flourished the information age for the last two decades.

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