

Survivability Analysis for IntelliDrive-Enabled Aging Traffic Aid System.

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ABSTRACT

The importance of ensuring safe traffic facilities for the aging population cannot be over-emphasized. The emergence of the IntelliDrive technology may serve as a solution to realizing this concern. This project seeks to propose an IntelliDrive-enabled traffic-aid system for the aging towards a survivable system that is both functional and safe in spite of unavoidable threats and attacks. We discovered that developing this kind of application will improve the safety and the efficiency of the transportation system while at the same time reducing the threats to the aging population in the form of accidents during a medical attack or getting lost due to failing health and memory as they navigate our roads and streets.

In order to gain public trust and confidence towards implementing this kind of system due to its criticality with respect to safety, we made attempt to integrate survivability capabilities to the system so as to mitigate risks that might serve as impediments towards the delivery of its essential services.

(Keywords: aging, IntelliDrive, survivability, intelligent transportation systems, ITS, fault tolerance)

INTRODUCTION

Intelligent Transportation Systems (ITS) can be described as sets of information and communication technologies that are used to efficiently manage and enhance the performance of transportation facilities and services (Genesee Transportation Council, 2003). This involves transportation infrastructure on highways, streets, railways, ports and bridges, which have different mode of employment like cars, buses, trucks, trains, ships, bicycles and pedestrians. When ITS is fully in place, some of the advantages are

improved mobility, security, safety and productivity. ITS over the years have been proposed to be fully efficient in the areas of traffic signal control, freeway management, transit management, incident management/emergency response, electronic toll collection, railroad crossings, and traveler information.

According to Administration on Aging (2010), persons that are 65 years old and above, regarded as the older population, numbered about 39.6 million in 2009 in the United States. This figure represented about 12.9% of the U.S. population (i.e., about one in every eight Americans). Considering the trend of American population growth, by the year 2030, it is expected that there will be about 72.1 million older persons. It was reiterated in NAPTA (2008) that isolation becomes a growing problem as people age and that mobility become increasingly critical needs.

When disaster strikes, aged people are the most affected because of their limited mobility and due to the difficulty locating them and getting them rescued quickly because of their physical or mental impairments. O'Brien (2011) reports that more than 33% of communities do not have a system to locate older persons who become ill or wander due to Alzheimer's or other forms of dementia. Aging Americans needs reliable means of transportation, a transportation system that takes into cognizance the needs of the aging. This will not only allow them to live independently, but will also allow them easy access to medical and social services. The older people need to be able to navigate the transportation system without danger or threats of accident/collision, being stuck unnecessarily in a hold up, experiencing medical attack without needed assistance while in a vehicle as a passenger or driver, on a scooter or even as a pedestrian.

Another report (Safe Transportation for an Aging Population, 2004) emphasized that as we age, our vision and hearing capabilities deteriorate significantly. Older people require about 10 times illumination more than those that are younger. The rate of walking and the information processing capability slow down as we continue to age. It is very essential that older pedestrians be given adequate time to cross roadways. The various infrastructures for transportation do age without significant changes to our roads, sidewalks, traffic signals and signs. Due to bad speed-distance judgment, traffic intersections are places that have the propensities for most fatal crashes involving aged drivers and pedestrians alike. The aged pedestrian most of the time are focused on watching their steps rather than vehicles in the streets trying to make a turn or backing towards them.

In recent times, the dailies and TV broadcasts are filled with reports of increased cases of kidnapping in which the aged who are most vulnerable are not left out. The transportation system requires a means of tracking/monitoring the where about and well-being of the aged or an alert systems to automatically signal treats like stress of the older community. All these factors make navigation of the aged through the present day transportation system very dangerous and necessitated the need for an Intelligent Transportation System that takes into cognizance the needs and survivability of the aged, especially those with failing/ill health that have the tendency of experiencing an attack at one time of the other.

Some of the questions that come to mind as we think of this technology integration are: What communication scheme should be employed for the proposed system? Since several players are involved, we need to consider infrastructures for vehicle-to-vehicle (cars, scooters, mopeds, trains, etc.) communication, vehicle-to-infrastructure/road-side (roadway, pedestrian) communication, fixed-point to fixed-point (traffic management center, emergency management center, security monitors and surveillance equipment) communication and wide area wireless (mobile) communications.

Another question that comes to mind in this setup is what are the benign and malicious threats to this system? This is very crucial because of the vulnerabilities of the aging population to attack and the need to ensure the trust and confidence of the users. There is also the need to consider

the essential services that this system would provide; knowing this will serve as a justification for its eventual implementation. To ensure that the essential services are survivable, we need to consider the mechanisms to be employed. Closely allied to this, the report will describe the system analysis methodology employed with respect to reliability, safety and risks associated with malicious threat.

In order to address the problems that pertain to how the aging population can survive using the ITS infrastructure and design issues mentioned earlier, the Survivability Network Analysis (SNA) methodology proposed by the CMU (Ellison et al., 1998) was adopted in our survivability analysis of the proposed system. We appraised the survivability of the system in the presence of attacks and vulnerabilities and came up with the end product i.e. a *survivability map* which is a table consisting of both the existing strategies that are used for tackling the identified survivability concerns as well as our suggested methodologies for survivability and graceful degradation in the presence of malicious attacks.

DEFINITION OF THE PROPOSED APPLICATION

The proposed application was defined with respect to its requirements, scope and functionalities to reflect the mission of the system.

System Mission

The mission of the generalized Intelligent Transportation System is to provide services that ensure the safety of the public as they navigate the Transportation system. The ITS system intends to use a combination of the existing infrastructures and some added facilities that facilitate Vehicle-to-Vehicle, Vehicle-to-Road, and Vehicle-to-Infrastructures communications. A report (ITS Security Area, 2010) stated that the ITS is a means of improving public safety and maximizing the use and efficiency of the existing multimodal transportation system. An emergency situation is reported, verified and the terms, and conditions of system activation are first satisfied before the agency responsible for broadcasting emergency information to other agencies like the traffic agencies, information service providers, etc., responds. The ITS system generates alert signals to the public using the ITS infrastructure in

the form of On-board displays, Highway Advisory Radio and other means that are easily understandable to the ITS users.

Normal Usage Scenarios (NUS) of the System

The incorporation of the Aging-Traffic Aiding facilities to the ITS will generate some of the following usage scenarios:

NUS1: The aging needing an emergency medical attention

NUS2: Emergency vehicle approaching warning/alert

NUS3: Intersection collision avoidance with aging scooter/vehicle

NUS4: Aging vehicle approaching/ahead warning

NUS5: Aging vehicle acting as a “threat vehicle” because of medical attack in progress – imminent collision warning.

NUS6: Aging already involved in an accident – warning to on-coming vehicle e.g. re-route, slow-down, initiate call for emergency, etc.

NUS7: Imminent collision preparation – warning and collision preparation message, seat belt tightening, side air bag deployment, side bumper expansion, etc.

NUS8: Emergency Response Centre – receiving notification of imminent collision and location address, monitoring of aging on-transit, responding and sending emergency dispatch to emergency location, etc.

NUS9: Providing on-board information for the aging – nearest medical centre, traffic information, nearest malls, etc.

NUS10: Tracking aging in public transit vehicles and as pedestrian on the street.

NUS11: Monitoring health condition of the aging and generating an alert for an impending medical attack e.g. heart attack, seizures, etc.

NUS12: Making available medical records of the aging at the accident/emergency site in order to know the type of medication or aid to be administered.

NUS13: Rail intersection warning for the aging in a car or scooter.

The above mentioned usage scenarios will require an enhancement to the existing generalized ITS architecture based on the principal functional requirements of ensuring seamless and security aware transportation system for the aging. The proposed enhanced architecture is therefore presented in the next section.

System Architecture

Figure 1 depicts the architectural components of the proposed system. This is essentially an extension to the existing ITS architecture. It was extended to incorporate several facilities and services that are required to allow the aging to take advantage of the ITS infrastructure in order to carry out their day-to-day activities without unnecessary threat from other users of the infrastructure. The extended ITS architecture could be described by two layers:

1) **Transportation Layer:** This shows the interaction among transportation management elements. These elements are travelers, vehicles, transportation management centers and field/roadside components that for instance, provide warning to approaching cars of potential problems such as accidents, obstacles in the road, or inclement weather conditions like ice. The field/roadside equipment includes thermal sensors capable of measuring the road temperature, optical sensors used for observing people on the road (e.g., aging and emergency service people at an accident scene), video cameras used for monitoring human at traffic management center or placed at locations with frequent problems for automated image analysis.

The **Emergency Management** subsystem is the agency that is responsible for broadcasting the emergency information to the ITS infrastructure. It provides alert information to the **Traffic Management** subsystem, the **Transit Management** subsystem, **Hospital Management** subsystem, **Information Service Providers**, Emergency Response Crew (**Emergency Vehicles**) and the rest of the travelling public. The Emergency Management subsystem is the ITS component in which the wide area security alert of the entire system centers around. According to the National ITS Architecture (Key

Concepts of the National ITS Infrastructures, 2009), it uses the ITS driver and Traveler Information systems to alert the public in emergency situations like severe weather events, child or an aging abduction, civil emergencies, accidents on road and other situations that might stand as a threat to life and properties. It generates alerts in form of information and instructions for the ITS system operators and the travelling public including the aging community.

necessary communications needed to exchange control and surveillance information provide capabilities that are associated with traffic signal control systems. These capabilities include surveillance of ITS system to collect network traffic conditions, control of intersections using different mechanisms like central monitoring of locally controlled signals, closed loop systems, adaptive control strategies and area-wide signal coordination (Key Concepts of the National ITS Infrastructures, 2009).

The **Roadway** subsystem and the **Traffic Management** subsystem, together with all the

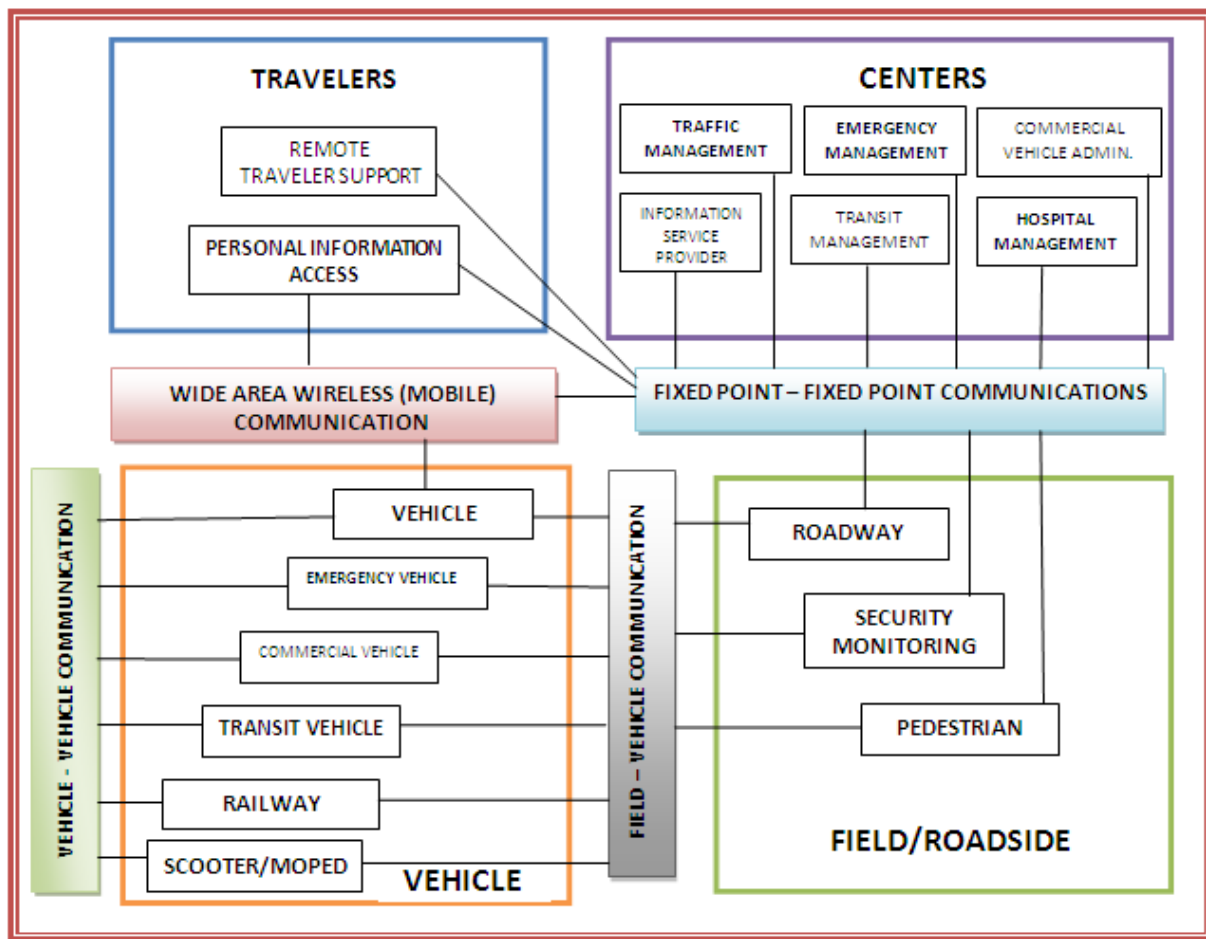


Figure 1: Architectural Components of the Proposed System.

2) **Communication Layer:** This layer provides essential communication services that link together the transportation layer components. The communication layer portrays all the communications that are essential in transferring information and data among the components that made up the enhanced ITS (vehicle-to-vehicle, vehicle-to-infrastructure). The different protocols necessary for these communications are also identified here based on the communication device under consideration. Since it is required that information must be location based in this enhanced ITS, the Dedicated Short-Range Communication (DSRC) is considered here to be well suited as the communication technique. This will enable aging's vehicles/scooter to receive real time information based on its exact location and correlate its location with the message received to determine if the message is of importance. This information might be presented to the aging in form of an audio alarm, a warning light, or a graphic display. The different communications possibilities in this enhanced ITS which are meant to aid aging easy transportation are described below.

(i) **Fixed-Point to Fixed-Point:** Fixed-Point-to-Fixed-Point Communications includes the equipment necessary for the various subsystems of the architecture, including the Traffic Management and Roadway subsystems, to exchange data to perform their transportation functions. These communications services may be provided by agency-owned communications plants (e.g. twisted pair, coaxial, fibre, or spread-spectrum radio), or may be leased from a communications service provider. Another essential communication device in a Fixed-Point to Fixed-Point communication is the use of Road-Side Unit (RSU). The RSU can communicate with another RSU through the wired infrastructure to provide communication for the ITS infrastructure.

(ii) **V2V communication:** The Dedicated Short Range Communication (DSRC) offers the potential to effectively support vehicle-to-vehicle safety communication in an ITS system. It enables new set of communication applications that will foster the overall safety and efficiency of the ITS system. The DSRC allows traffic information, emergency alerts, collision impending alerts, aging position location and medical alert information to be relayed from one vehicle to another. It allows one way communication of vehicles to send a broadcast message to other vehicles and also a two-way

communication which establishes dialogues among vehicles as they traverse the ITS system. The type of DSRC devices used for vehicle-to-vehicle communication is the On-Board Unit (OBU). Each vehicle is equipped with an OBU that is a type of transceiver with a processor mounted within a vehicle. The vehicles have omni-directional antenna that the OBU uses to access the wireless channel. Each vehicle has sensors that provide input to the OBU. The sensors provide local conditions of the vehicle (Guo and Balon, to appear). The aging vehicle equipped with an OBU will be able to establish communication with other vehicles to signal the presence of an aging nearby, thereby preventing collision in an intersection or collision during when an aging is experiencing a medical attack.

(iii) **V2I or V2R Communication:** The Roadway subsystem roles are essentially implemented with equipment found in the field, for instance, the traffic signal controllers, traffic lights, vehicle detectors, video camera and the Road-Side Unit (RSU). The Traffic Management subsystem functions are realized with equipments that are centrally found in the traffic centers like computers, traffic control consoles, video switching and display systems [8]. The RSU are stationary type of DSRC devices mounted on the road side, like the OBU has transceiver, antenna, processor and sensors. They are placed along the road like intersections to improve the flow of traffic through intersection and to reduce accident. The aging in vehicles, scooters or as a pedestrian could be equipped with sensors and OBUs that could communicate wirelessly with the RSU. This will enable the location of an aging to be identified either when facing a medical attack, risk of being kidnapped and other incidences like accident, lost on transit due to failed memory, etc.

(iv) **Wide Area Wireless Communication:** This is the communication that spans the entire coverage area of the enhanced ITS infrastructure that are strictly wireless. These include wireless devices that are used to implement long-range communications, short-range communications, vehicle-to-vehicle communications and vehicle-to-infrastructure communications. The Wide Area Wireless Communications could be implemented with combinations of devices like the Dedicated Short-Range Communications (DSRC), Cellular Communications, Bluetooth, WiFi, WiMAX, Satellite Communications (voice, data, and paging), Satellite Broadcasting (radio and television), Geospatial Positioning, etc.

Operating Environment

The Transportation systems are composed of some subsystems operating on a distributed network of Road Side Equipments, On-board Equipments, Patients Equipments, computers, clients and servers that maintain large and complex databases for different centers distributed over the whole country such as Traffic Management, Emergency Management, Commercial Vehicle Administration, Information Service Provider, Transit Management and Hospital Management.

ESSENTIAL CAPABILITY DEFINITION

Essential Services

The essential services are the services that need to be delivered by the enhanced ITS infrastructures for it to be certified to have fulfilled its designed mission. These services include:

- Driver has to be able to send a warning to the emergency management via vehicle to vehicle and vehicle to infrastructure networks (IntelliDrive Infrastructure).
- The emergency management should be able to report that to the traffic management to warn other drivers and to hospital management to send an emergency vehicle to the aging driver.
- It is too important to ensure the communication between the drivers using the medical equipments, OBU, RSU vehicle to infrastructure, to the emergency center within proper time.

Essential Assets

The essential assets are the various components that are needed by the system in order to carry out its mission. They include:

- Emergency Management Center and its equipment.
- Aging means of transportations
- Aging Tracking Devices
- Alert generating devices
- Sensing devices
- Alert Relaying devices

- Distributed equipments and vehicle to infrastructure.
- The equipments required for communications infrastructure.

Essential Components

The essential components include:

- All communication channels as shown in the previous figure.
- All communication devices such as medical sensors, OBU, RSU, wireless sensors, switches, servers, firewalls, routers, storage and backup devices.
- Traffic Controller one of the most important and essential components in Transportation systems.

COMPROMISABLE CAPABILITY DEFINITION

Identifying Intrusion Scenarios

The following are different intrusion scenarios that were identified in the proposed system:

IUS 1: False warning/alarm about accident, traffic congestion, an aging within the vicinity of a vehicle or at a junction in a car, scooter or as pedestrian.

IUS 2: False or spurious emergency request – made to the Emergency management Center, emergency response team vehicles, etc.

IUS 3: Hijacking of ITS components like Traffic Management and Emergency management centers for malicious act like terrorism, etc.

IUS 4: Denial of Service attack against the aging not having access to emergency response team during an attack, emergency management centre not able to contact the emergency response unit about an accident, aging needing medical attention as a result of a medical attack.

IUS 5: Denial of service to other road users not being able to identify the presence or nearness of an aging in traffic.

IUS 6: Taking advantage of the position location devices attached to aging vehicles, scooters and body to perpetrate kidnapping.

IUS 7: Misdirecting the aging to wrong destinations.

IUS 8: Supplying wrong medical information about aging to the emergency response team during a medical attack.

IUS 9: Congesting or jamming communication equipment between the aging and the emergency response center to increase emergency response time.

IUS 10: Stealing of aging vital information like Social Security Number from the Hospital Management Center database e.g. breaking passwords, spoofing, sniffing, using Trojan, man-in-the-middle attack etc.

IUS 11: Modifying medical records of aging in the Hospital Management Center database e.g. getting physical access to some devices.

- OBU on emergency response vehicles
- Information Service Provider equipment
- Hospital Management equipment– database, servers, backups.
- Vehicle Classification Sensors – can detect the class of vehicle moving past them.

SURVIVABILITY ANALYSIS

Identifying Softspot Components

In this step, the softspot components which are both essential and compromisable are identified from the normal and intrusion scenarios. The softspot components identified are traffic controllers, databases at the various management centers, network infrastructures and communicating equipment used.

Developing Survivability Map

We here carried out the analysis of how survivable the proposed system is in the presence of attacks and vulnerabilities as listed in the identified intrusion scenarios with respect to resistance, recognition, and recovery. The result of this analysis is presented in Table 1 which serves as the survivability map for the proposed system. The table presents both the current existing strategies that are in place to tackle the listed survivability concerns as well as our suggested methodologies towards ensuring its survivability and graceful degradation in the presence of malicious attacks.

Compromisable Components Identification

Below is a list of components that are compromisable in the enhanced ITS infrastructure as a result of the above mentioned intrusion scenarios:

- Emergency Management Centre components –Computer Aided Dispatch (CAD) with Automated Vehicle Locator,
- Traffic Management Centre components
- Tracking devices on aging
- OBU devices on aging vehicles and scooters – on-board video surveillance,
- Road-Side Units

Table 1: The Survivability Map.

Intrusion scenarios	Resistance strategy	Recognition strategy	Recovery strategy
IUS1: False warning/alarm about accident, traffic congestion, an aging within the vicinity of a vehicle or at a junction in a car, scooter or as pedestrian.	Current: None	Current: None	Current: None
	Recommended: Encryption technique and strong authentication mechanisms.	Recommended: Validation techniques and intrusions detection system.	Recommended: Using some kind of redundancy with fault tolerance mechanisms.

IUS 2: False or spurious emergency request – made to the Emergency management Center, emergency response team vehicles, etc.	Current: None	Current: None	Current: None
	Recommended: Encryption technique and strong authentication mechanisms.	Recommended: Validation techniques and intrusions detection system	Recommended: Using some kind of redundancy with fault tolerance mechanisms
IUS 3: Hijacking of ITS components like Traffic Management and Emergency management centers for malicious act like terrorism, etc.	Current: Restricted access to those components and centers, use of physical security devices such as alarming system and cameras.	Current: None	Current: None
	Recommended: Use of IDS to restrict illegal use of the system.	Recommended: Using Alarm system And by using the log file in the fingerprint systems.	Recommended: Triggering of auto shut-down procedure if illegal use of system is detected. Set all ITS components to default mode, locate and isolate source of threats and restore the system to normal operation. Alert the FBI.
IUS 4: Denial of Service attack against the aging not having access to emergency response team during an attack, emergency management centre not able to contact the emergency response unit about an accident, aging needing medical attention as a result of a medical attack.	Current: None.	Current: None	Current: None.
	Recommended: Use of firewalls and Automated Incident Detection System.	Recommended: Use of IDS.	Recommended: Developing a Roll-back Recovery strategy, isolate source of attack and restore denied services.
IUS 5: Denial of service to other road users not being able to identify the presence or nearness of an aging in traffic.	Current: None.	Current: None	Current: None.
	Recommended: Use of firewalls.	Recommended: Intrusion detection systems	Recommended: Null-out attackers IP and Null-route the aging IP until the attacks subsides. Can also use Adaptive Control strategies.

IUS 7: Misdirecting the aging to wrong destinations.	Current: None	Current: None	Current: 911 calls
	Recommended: Authenticating Route Discovery Devices and validating their suggested routes.	Recommended: Use of Real-time monitoring devices of the aging location.	Recommended: Use of Panic Button and re-routing devices like GPS and Automatic Vehicle Locator.
IUS 8: Illegal access to the ITS network and consequently Supplying wrong medical information about aging to the emergency response team during a medical attack.	Current: Password	Current: None	Current: None
	Recommended: Authentication combined with Encryption.	Recommended: Intrusion detection systems	Recommended: Use of redundant storage devices that aid fault tolerance recovery process like the use of agreement algorithms to validate data retrieved from the storage devices. Alerting law enforcement agents.
IUS 9: Congesting or jamming communication equipment between the aging and the emergency response center to increase emergency response time.	Current: None	Current: None	Current: None
	Recommended: Effective routing mechanisms that incorporate Multiple paths concept and using of distributed data storage mechanisms.	Recommended: Use of collision/congestion detection mechanisms, IDS and firewalls.	Recommended: Re-routing requests and isolating sources of jamming.
IUS 10: Stealing of aging vital information like Social Security Number from the Hospital Management Center database e.g. breaking passwords, spoofing, sniffing, using Trojan, man-in-the-middle attack etc.	Current: Use of password and encryption.	Current: Use of Virus software.	Current: None.
	Recommended: Use of functional distributed data storage that enhances strong authentication and encryption.	Recommended: Use of Intrusion detection system and Identity theft monitoring mechanisms.	Recommended: Tracking usage of identity information, Nullifying stolen identity information or alerting the law enforcement agents and credit bureau.

IUS 11: Modifying medical records of aging in the Hospital Management Center database e.g. getting physical access to some devices.	Current: Use of password	Current: None	Current: None
	Recommended: Using efficient distributed data storage policies that foster strong authentication and encryption, use of firewalls.	Recommended: Validation techniques and Intrusions Detection System.	Recommended: Isolate source of attack and functionalities affected and trigger a system roll-back recovery procedure.

CONCLUSION

In this project we proposed the enhanced ITS architecture that ensures delivery of essential services to the aging community as they navigate the ITS infrastructure. Since any malicious manipulation would strongly undermine public trust in the proposed, we applied the CMU's Survivable Network Analysis (SNA) methodology to analyze the system for vulnerabilities and possible intrusion scenarios. We developed a survivability map which contains the list of intrusion scenarios, the current approaches to handling these threats with respect to attack resistance, recognition and recovery.

The survivability map also contains our recommendations for each of the existing strategies to make the system survivable in spite of inevitable threats and malicious attacks. We discovered that the SNA methodology is very useful when dealing with systems that are very large, that have critical infrastructures that are expected to function at all time and that are expected to degrade gracefully under massive attacks.

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