Reliability and Throughput in Future Automotive Communication Networks

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In 1995, GM started to offer automatic crash notification services through OnStar. This action created a new industry called automotive telematics, helping to save lives and providing assistance to millions of people, including high school students to senators. In the past decade, the automotive telematics industry has experienced a healthy growth in North America. During the current economic downturn, the automotive telematics industry has grown worldwide surprisingly faster than prediction. However, new challenges in reliability and throughput have also emerged in the automotive telematics industry as wireless networks have migrated much faster than automotive telematics systems. These challenges need to be studied and solved so that the reliability of future automotive telematics systems can be improved and their functions/services can be expanded as demanded. Meanwhile, it is important to maintain the leadership of the American automotive OEMs in the global automotive telematics market.

In 2009, OnStar installed its 9th generation system in all of GM vehicles. In December 2009, OnStar launched a call center in Shanghai for GM customers in China. ATX, a privately held company in San Antonio, Texas, started its service Lincoln RESCU in 1996 on the Lincoln Continental in partnership with Ford and Motorola. ATX provides services to many automobile brands including BMW, Mercedes-Benz, PSA Peugeot Citroën Maybach, Rolls-Royce Motor Cars, and Toyota. In the global economic downturn, the automotive telematics has grown faster. In March 2009, Ford began offering Web access and E911 assistant calls in the SYNC system as an option to drivers through Sprint Nextel wireless network. By February 2010, Ford already had over one million customers in the telematics system. Meanwhile, Toyota has launched new safety and driver assist programs on certain Toyota and Lexus models in North America and China, a major competition against OnStar.

In 2009, the European Commission passed legislation to make the eCall system mandatory starting 2014. The eCall system is the European emergency call system for automobiles. With functions very similar to the OnStar system, the eCall system provides automatic crash notification and phone call services, etc. The eCall standard has become a part of the 3GPP mobile communication standards aligned with the 4G LTE.

Today, automotive telematics provides safety, security, and convenience services to drivers. Among the many service options, the most popular service is OnStar's Automatic Crash Response (ACR). In the event of a crash, sensor networks in vehicles can detect the impact and the number of people in the vehicle, transmit the critical data with the vehicle location from onboard GPS receivers, and alert OnStar service representatives through a cellular link. If a driver cannot respond, a representative can request emergency help to be sent to the vehicle. This application requires the highest possible availability for the link between the vehicle and the service center, in every kind of crash severity. Although cellular, PCS and satellite links are each reasonably ubiquitous and reliable, increased robustness of the ACR radio frequency link is critical

to not only saving lives, but also to everyday communications in current and future applications.

One way to increase robustness is to introduce redundant wireless links. Besides safety applications, such as ACR, a myriad of emerging telematics applications are driving auto manufacturers to consider additional types of wireless connectivity (e.g. WiFi, WiMax, and broadcast technologies). Existing multi-band antennas have obviated the need to place more than three antennas on a vehicle. It is the rest of the current communications architecture that has become unwieldy. Cellular/PCS/AWS, satellite radio, AM, FM, and GPS all have their own low-noise amplifiers (LNAs), downconverters, analog-to-digital converters (ADCs), and signal processing engines. Such multi-transceiver implementations have high piece costs as well as software and hardware underpinnings that are expensive to maintain. In addition, the inherent lack of flexibility forces the introduction of both new hardware and software to accommodate any new physical channel.

One solution GM R&D and other automobile manufacturers are considering is a single wideband RF front-end with one ADC that will support as many radio links as feasible. The objective is to reduce system and maintenance costs, improve system flexibility, and increase data throughput to each vehicle.

Dr. Macdonald, Dr. Liu, and Dr. Talty have demonstrated a concept multiband RF receiver in the frequency range [0.8, 3] GHz and successfully collected data using the multiband RF receiver at 72 locations in Metro Detroit area. A testbed with the receiver installed on GM vehicle was designed, built, and employed for experiments. In the next 5 years, we expect to develop theory and methods for multiband mobile communications, expand the testbed for more experiments, demonstrate multiband mobile communication transceiver and network for automotive applications. In 10 years, we expect such systems to be adopted by future vehicle platforms and help the American automotive industry to become more competitive in the global market.

Simultaneous mobile communications through multiple RF bands using an integrated RF frontend and hardware is a novel approach. It can open doors for researchers in computer networks, traffic engineering, protocol design and analysis, concurrent real time programming, high speed real time CPU design and implementation, RF engineering and communications. Through the workshop, researchers can be introduced to this area, and team up to get work done for the American automotive industry.

GM started the automotive telematics industry. The standardization of the European eCall system has shown that the eCall system can outperform competitor systems in the USA. Great effort is needed for Americans to catch up with the Europeans in core technology for automotive telematics. In 2009, the automotive sales was 14.48 million in EU, 13.64 million in China, and 10.43 million in North America. As the American automotive OEMs are trying to have larger market shares in EU and China, it is very important for Americans to make progress in automotive telematics, including better research/technology and products.

John Liu received the B.S. degree in electronics and the M.S. degree in computer science from Peking University, Beijing, China, in 1990 and 1992, respectively, the M.S. degree in electrical engineering from New Mexico State University, Las Cruces, in 1993, and the Ph.D. degree in electrical engineering from the University of Southern California, Los Angeles, in 1996. From 1996 to 2000 he was a Senior Member of Technical Staff with Hughes Network Systems. He is editor, *IEEE Transactions on Communications*, director, Electrical Vehicle Laboratory, Advanced Communications Laboratory, Associate Professor at Wayne State University, Detroit, MI. His current research interests include automotive telematics, automotive radar, embedded systems, electrical vehicle, radio network security, communications networks, ultra-wideband communications, optical wireless communications, modulation and coding, synchronization, signal design and detection.

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