Position Paper: Decentralized Vehicle Decisioning Network

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Introduction

With the advent of pervasive computing devices with small form and energy factors, an explosion of machine-to-machine communication opportunities have appeared. Over the past decade we have labeled, identified (RFID, UID) and integrated (Internet, SAT communication, GPRS, WIFI/WIMAX, Bluetooth, Zigbee) billions of physical objects into systems that interact in a secure and manageable way. In the automotive sector in 2005, GE embarked on a multimillion dollar/multiyear effort to create an intelligent network of objects that can perceive their surroundings, interact with each other, learn, and make decisions individually or as part of a group. Assembled from traditional electronic components, these intelligent agents are now built into more than 200,000 devices that roam the world on the backs of a variety of objects such as tractor-trailers, automobiles, railcars, and cargo containers, as shown in Figure 1.

Based on this type of decentralized vehicle decisioning platform (a Super Sensor Network), we can build intelligent systems for environmental sensing, global supply chain optimization, traffic-aware vehicle networks, location-based digital content delivery, and many others. For example, vehicles located in the same geographical region can share information such as travel time, speed, direction, destination, and idling time. Traffic information such as congestion, length of traffic jam, and estimated travel time will then emerge collectively from the interactions of the vehicles. Such a system can even be used for the prediction of traffic related events (such as a traffic jams) and therefore act proactively to optimize individual vehicle routes.

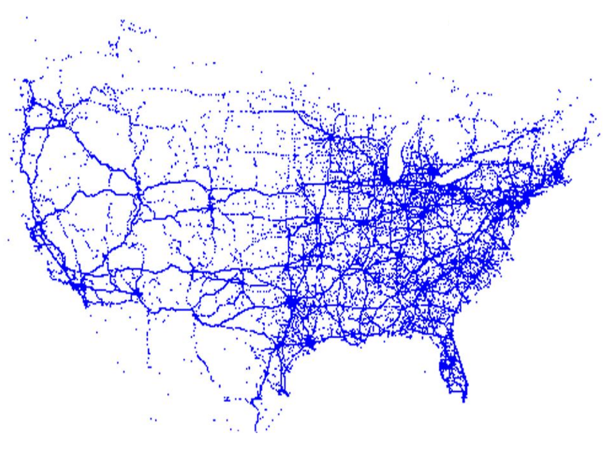

Figure 1: Decentralized vehicle decisioning network made up of more than 200,000 GE-managed assets such as tractor-trailers, automobiles, railcars and cargo containers.

We envision that this type of decentralized vehicle decisioning network will be a vital technology environment for cyber-physical infrastructure. However, many issues need to be addressed as discussed below.

Current Limitations

1) **Data Explosion and Information Superiority**: As ubiquitous sensors and microprocessors proliferate, the torrent of data streams has begun to bring traditional IT structures and business systems to their knees [1]. In 2007, the size of the digital universe (the amount of information created, captured, and replicated) surpassed the amount of physical storage available on the planet [2]. The time and money required to traditionally solve the problem with a central control system often outweighs the utility of the solution. Efficient ways are needed to handle distributed information, to know what is important and what is not, what needs to be kept and what needs to forgotten.
2) **Processing Power and Bandwidth Cost:** A system of this scope often requires multiple hardware architectures and operating systems running in diverse environments and operating conditions. As bandwidth and edge device processing power increases, utilizing remote, fault-tolerant resources becomes feasible through the use of distributed computing frameworks. Processor-intensive tasks like image processing and data analysis can be shared amongst multiple systems through local area networks. Efficient middleware and a fault-tolerant architecture are required to ensure maximum decisioning capability, even when the system is stressed.
3) **Individual Decision-Making Process in the Vehicle**: Currently, decision-making in a moving vehicle is largely handled by the vehicle operator. The operator is called upon to make decisions ranging from micro-movement course corrections and emergency braking, through route planning in varying traffic and road conditions, to dynamic scheduling requirements. Factors such as the problem of scale, the ability to get information to decision makers in a timely manner, and highly coupled decision-making in an environment where relevant information is localized, need to be considered.

Other technology gaps include heterogeneous network scalability, fault tolerance, distributed shared memory and personal freedom.

Recommended Solution

We propose to build a system-level “consciousness” that will be multi-purposed and operate in a distributed network with many of the attributes of collective intelligence [3]. The solution is to combine traditional centralized planning with distributed localized decision making systems based on inherent machine intelligence.

Collective intelligence is a form of intelligence that emerges from the collaboration of many individuals with unsophisticated intelligence following simple but rigorous rules. There is no central management where the individuals send their information to and receive decisions from. Instead, the information is exchanged in range-limited but target-relevant groups and the decisions are made based on the interactions among individuals and with the environment. No single individual is necessarily aware of the state of the entire system nor does any individual directly control other individuals, but collectively the system behaves intelligently and executes high-level complex behavior.

The collective system is robust enough to resist disruptions such as individual and communication network failures due to the lack of a top-down control structure. For this reason it also requires less communication and therefore less network bandwidth. Furthermore, the collective system is self-organizing, easily adaptive to changing environments, and highly scalable.

Bios

Charles Theurer

Dr. Charles Burton Theurer is in his fourth year in the Pervasive Decisioning Systems Laboratory at GE Global Research. In this time he has developed technologies in networking and telematics that have helped set the vision and enabled the organic growth of a new GE telematics-based business. He has over five years of experience in electromechanical systems design with an emphasis on energy harvesting and wireless communication through solid media. He has worked on projects ranging from dynamic control of intelligent systems to knowledge based engineering systems to web-based systems for automated cost forecasting. Charles has several engineering design awards including a national merit award for design, and a scholarship for excellence in design engineering.

Li Zhang

Dr. Li Zhang received his Ph.D. degree from the University of Massachusetts Amherst in 2004. He is currently a research scientist in the Pervasive Decisioning Systems Lab of the GE Global Research Center. His research interests include collective intelligence, wireless communication, pervasive connectivity, electromechanical systems design, smart sensing systems, and machine condition monitoring.

Qing Cao

Dr. Qing Cao is a researcher at the Pervasive Decisioning Systems Lab at GE Global Research. Dr. Cao's current research focuses on systems design, pattern recognition, content-based retrieval, network models and other decisioning methodologies, with applications in pervasive telematics systems. Dr. Cao received her Ph.D. in Mechanical Engineering from Massachusetts Institute of Technology in 2006, specialized in Design Methodology and Product Development. She received her B.S. and M.S in Automated Control from Tsinghua University in 1997 and 2000 respectively.

References

1. Balazinskaet M. et al., "Data Management in the Worldwide Sensor Web", IEEE Pervasive Computing, Volume 6, Issue 2, 2007.
2. Gantz, John F. et al. "The Expanding Digital Universe". IDC White Paper, March 2007. p.1
3. Eberhart, R. C. et al., "Swarm Intelligence", Morgan Kaufmann , 2001.