A comparative analysis on Sensor Networks

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Abstract—Sensor networks are emerging as one of the most important technologies for the 21st century. In this paper we have traced out the research in sensor networks over the past three decades, and also the development of sensor networks and the challenges faced in developing sensor networks. Various technical challenges faced in sensor network development includes network discovery, control and routing, collaborative signal and information processing, tasking and querying, and security are also discussed. This paper is concluded by presenting some recent research results of distributed tracking in wireless ad hoc networks, and distributed classification using local agents.

Index Terms—sensors, Collaborative signal processing, wireless networks.

I. Introduction

A sensor network is spatially distributed independent sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to transmit their data through a network to a desired location. Business Week one of the prominent magazine acclaimed sensor networks as one of the twenty one most useful technologies for the 21st century. Low cost, smart device with multiple onboard sensors, networked through wireless network and the Internet and deployed in huge numbers, provides enormous opportunities for instrumenting homes, cities, and the environment. A system of networked sensors is capable of detecting and tracking threats (e.g., winged and wheeled vehicles, personnel, chemical and biological agents) and can also be used for weapon targeting and area denial. Various applications of sensor networks include: military sensing, physical security, air traffic control, traffic surveillance, video surveillance, industrial and manufacturing automation, distributed robotics, environment monitoring, and building and structures monitoring. The sensors in these applications may be small or large, and the networks may be wired or wireless. This paper will present a history of research in sensor networks, technology trends, new applications, research issues and hard problems.

II. RESEARCH HISTORY IN SENSOR NETWORKS

In order to develop the sensor network requires developing technologies from three different areas: sensing, communication, and computing. Thus, there is a need of combined and separate research in each of these areas. Traditionally, sensor networks include the radar networks used in air traffic control. The national power grid, with its many sensors, can be viewed as one large sensor network. These all systems were basically developed with specialized computers. During the Cold War, the Sound Surveillance System (SOSUS), a system of acoustic sensors, was deployed in order to detect and track quiet Soviet submarines. Over the years, other more sensor networks have been developed for submarine surveillance. SOSUS is now used by the National Oceanographic and Atmospheric Administration (NOAA) for monitoring events in the ocean, e.g., seismic and animal activity. Also during the Cold War, networks of air defense radars were developed and deployed to defend the United States and. This air defense system has emerged over the years to include aerostats as sensors and Airborne Warning and Control System (AWACS) planes, and is also used for drug prohibition. These sensor networks generally adopt a hierarchical processing structure where processing occurs at consecutive levels until the information about events of interest reaches the user

III. Distributed Sensor Networks Program at the Defense

Advanced Research Projects Agency(ARPA) had researched on sensor networks which started around 1980 with the Distributed Sensor Networks (DSN) program at the Defense Advanced Research Projects Agency (DARPA). But By this time, the Arpanet (predecessor of the Internet) had been used for a number of years, with about 200 hosts at universities and research institutes. . Various technology components for a DSN were identified in a Distributed Sensor Nets workshop in 1978. These included sensors (acoustic), processing techniques and algorithms, and distributed softwar. Since, at that time DARPA was sponsoring much artificial intelligence (AI) research, the workshop also included discussion on the use of AI for understanding signals, as well as various distributed problem-solving techniques. Since very few technology components were available off at that time, therefore resulting DSN program had to address distributed computing support, signal processing, tracking, and test beds. Distributed acoustic tracking was chosen as the target problem for demonstration. All this was demonstrated in an indoor test bed with signal sources, acoustic sensors, and VAX computers connected by Ethernet. Researchers have focused on knowledge-based signal processing techniques for tracking aircrafts using a distributed array of acoustic microphones by means of signal abstractions and matching techniques. Signal abstractions view signals as consisting of multiple levels, with higher levels of abstraction (e.g., peaks) obtained by suppressing detailed information in lower levels (e.g., spectrum). They provide a conceptual framework for thinking about signal processing systems that resemble what

people use when interactively processing and interpreting real-world signals. By incorporating human heuristics, this approach was
designed for high signal-to-noise ratio situations where models are lacking. sing chain, tracking multiple targets in a distributed environment is significantly more difficult than centralized tracking. This sensors were acoustic arrays. A PDP11/34 computer and an array processor processed the acoustic signals. The nodal computer (for target tracking) consists of three MC68000 processors with 256-kB memory and 512-kB shared memory, and a custom operating system. Communication was by Ethernet and microwave radio. The DSN test bed was carried out with low altitude flying aircraft, which was successfully tracked with acoustic sensors as well as TV cameras.

IV. MILITARY SENSOR NETWORKS IN 1980S AND 1990S

Although early researchers on sensor networks had large numbers of small sensors, the technology for small sensors was not quite apt. However, planners of defense systems quickly analysed the benefits of sensor networks, which become a crucial component of network-centric warfare. In platform-centric warfare, platforms owns particular type of weapons, which in turn own sensors in a fairly rigid architecture. In other sense, sensors and weapons were mounted with and controlled by separate computers that operate independently. In network-centric warfare, sensors do not belong to weapons or platforms. Instead, they are linked with each other over a communication network. Sensor networks can improve detection and tracking performance through multiple records, geometric and diversity, extended detection range, and faster response time. Also, the development cost is comparable cheaper by exploiting commercial network technology and common network interfaces. An example of network-centric warfare is the Cooperative Engagement Capability (CEC) developed by the U.S. Navy. This system consists of multiple radars collecting data on air targets. Measurements are associated by a processing node "with reporting responsibility" and shared with other nodes that process all measurements of interest. Since all nodes have access to essentially the same information, a "common operating picture" essential for consistent military
operations is obtained. Other military sensor networks include acoustic sensor arrays for antisubmarine warfare such as the Fixed Distributed System (FDS) and the Advanced Deployable System (ADS), and unattended ground sensors (UGS) such as the Remote Battlefield Sensor System (REMBASS) and the Tactical Remote Sensor System(TRSS).

V. SENSOR NETWORK RESEARCH IN 21ST CENTURY

Recent advancement in electronics and communication have caused a substantial shift in sensor network research. Compact and cheap sensors based upon microelectromechanical system (MEMS) technology, wireless networking, and low cost, low-power processors allow the deployment of wireless ad hoc networks for various applications. Again, DARPA started a research program on sensor networks to purchase the latest technological advances. The report from DARPA Sensor Information Technology (SensIT) program pursued two key research observations. First, it developed new networking techniques. In the battlefield context, these sensor devices or nodes should be ready for rapid deployment, in an ad hoc fashion, and in highly dynamic environments. Today's networking techniques, developed for voice and data and relying on a fixed infrastructure, will not suffice for battlefield use. Thus, the program developed new networking techniques suitable for highly dynamic ad hoc environments. The second observation was networked information processing, i.e., how to extract useful and reliable, and timely information from the deployed sensor network. This means leveraging the distributed computing environment created by these sensors for signal and information processing in the network, and for dynamic and interactive querying and tasking the sensor network. SensIT generated new capabilities relative to today's sensors. Current systems such as the Tactical Automated Security System (TASS) [23] for perimeter security are dedicated rather than programmable. They use technologies based on transmit-only nodes and a long-range detection paradigm. SensIT networks have new capabilities. The networks are interactive and programmable with dynamic tasking and querying. A multitasking feature in the system allows multiple simultaneous users. Finally, since detection ranges are much shorter in a sensor system, the software and algorithms can exploit the proximity of devices to threats to drastically improve the accuracy of detection and tracking.
The software and the overall system design supports low latency, energy-efficient operation, built-in autonomy and survivability, and low probability of detection of operation. As a result, a network of SensIT nodes can support detection, identification, and tracking of threats, as well as targeting and communication, both within the network and to outside the network, such as an overhead asset.

VI. TECHNOLOGY TRENDS

Current sensor networks can exploit technologies not available 20 years ago and perform functions that were not even dreamed of at that time. Sensors, processors, and communication devices are all getting much smaller and cheaper. Commercial companies such as Ember, Crossbow, and Sensorial are now building and deploying small sensor nodes and systems. These companies provide a vision of how our daily lives will be enhanced through a network of small, embedded sensor nodes. In addition to products from these companies, commercial off-the-shelf personal digital assistants (PDAs) using Palm or Pocket PC operating systems contain significant computing power in a small package. These can easily be "ruggedized" to become processing nodes in a sensor network. Some of these devices even have built-in sensing capabilities, such as cameras. These powerful processors can be hooked to MEMS devices and machines along with extensive databases and communication platforms to bring about a new era of technologically sophisticated sensor nets. Wireless networks based upon IEEE 802.11 standards can now provide bandwidth approaching those of wired networks. At the same time, the IEEE has noticed the low expense and high capabilities that sensor networks offer. The organization has defined the IEEE 802.15 standard for personal area networks (PANs), with "personal networks" defined to have a radius of 5 to 10 m. Networks of short-range sensors are the ideal technology to be employed in PANs. The IEEE encouragement of the development of technologies and algorithms for such short ranges ensures continued development of low-cost sensor nets. Furthermore, increases in chip capacity and processor production capabilities have reduced the energy per bit requirement for both computing and communication. Sensing, computing, and communications can now be performed on a single chip, further reducing the cost and allowing deployment in ever larger numbers. Looking into the future, we predict that advances in MEMS technology will produce sensors that are even more capable and versatile. For example, Dust Inc., Berkeley, CA, a company that sprung from the late 1990s Smart Dust research project at the University of California, Berkeley, is building MEMS sensors that can sense and communicate and yet are tiny enough to fit inside a cubic millimeter. ecent advancement in electronics and communication have caused a substantial shift in sensor network research. Compact and cheap sensors based upon microelectromechanical system.

VII. CHALLENGES

Sensors networks in general pose considerable technical problems in data processing, communication, and sensor management (some of these were identified and researched in the first DSN program). Because of potentially harsh, uncertain, and dynamic environments, along with energy and bandwidth constraints, wireless ad hoc networks pose additional technical challenges in network discovery, network control and routing, collaborative information processing, querying, and tasking. A. Network Control and Routing The network must deal with resources—energy, bandwidth, and the processing power—that are dynamically changing, and the system should operate autonomously, changing its configuration as required. Since there is no planned connectivity in ad hoc networks, connectivity must emerge as needed from the algorithms and software. Since communication links are unreliable and shadow fading may eliminate links, the software and system design should generate the required reliability. This requires research into issues such as network size or the number of links and nodes needed to provide adequate redundancy. Also, for networks on the ground, RF transmission degrades with distance much faster than in free space, which means that communication distance and energy must be well managed. Protocols must be internalized in design and not require operator intervention. Alternative approaches to traditional Internet methods [such as Internet Protocols (IP)], including mobile IP, are needed. One of the benefits of not requiring IP addresses at each node is that one can deploy network devices in very large numbers. Also, in contrast to the case of IP, routes are built up from geoinformation, on an as-needed basis, and optimized for survivability and energy. This is a way to form connections on demand, for data-specific or application-specific purposes. IP is not likely to be a viable candidate in this context, since it needs to maintain routing tables for the global topology, and because updates in a dynamic sensor network environment incur heavy overhead in terms of time, memory, and energy. Survivability and adaptation to the environment are ensured through deploying an adequate number of nodes to provide redundancy in paths, and algorithms to find size, and density of nodes per square mile affect the tradeoffs between latency, reliability, and energy.

A. Tasking and Querying

A sensor field is like a database with many unique features.

Data is dynamically acquired from the environment, as opposed to being entered by an operator. The data is distributed

across nodes, and geographically dispersed nodes are connected by unreliable links. These features render the database view more challenging, particularly for military applications given the low-latency, real-time, and high-reliability requirements of the battlefield. It is important that users have a simple interface to interactively task and query the sensor network. An example of a human-network interface is a handheld unit that accepts speech input. The users should be able to command access to information, e.g., operational priority and type of target, while hiding details about individual sensors. One challenge is to develop a language for querying and tasking, as well as a database that can be readily queried. . Other challenges include finding efficient distributed mechanisms for query and task compilation and placement, data organization, and caching. Mobile platforms can carry sensors and query devices. As a result, seamless internetworking between mobile and fixed devices in the absence of any infrastructure is a critical and unique requirement for sensor networks. For example, an airborne querying device could initiate a query, and then tell the ground sensor network that it will be flying over a specific location after a minute, where the response to the query should be exhilarated.

B. Security

Since the sensor network may operate in a hostile environment, security should be built into the design and not as an afterthought. Network techniques are needed to provide low-latency, survivable, and secure networks. Low probability of detection communication is needed for networks because sensors are being envisioned for use behind enemy lines. For the same reasons, the network should be

protected again intrusion and spoofing.

VIII. CONCLUSIONS

Thus we can conclude that Sensor networks are emerging as one of the most important technologies for the 21st century. In this paper we have traced out the research in sensor networks over the past three decades, and also the development of sensor networks and the challenges faced in developing sensor networks. Various technical challenges faced in sensor network development includes network discovery, control and routing, collaborative signal and information processing, tasking and querying, and security are also discussed. This paper is concluded by presenting some recent research results of distributed tracking in wireless ad hoc networks, and distributed classification using local agents

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