# CS237 SURVEY PAPER

# Collaborative sensing in Mobile (P2P based)

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## INTRODUCTION:

To introduce the concept of collaborative sensing, it is necessary to explain the concept of “wireless sensor network” and “sensor web” first. A Wireless Sensor Network consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding. [1][2] The term "Sensor Web" was first used by Kevin Delin of NASA in 1997[3], to describe a novel Wireless Sensor Network architecture where the individual pieces could act and coordinate as a whole. In this sense, the term describes a specific type of sensor network: an amorphous network of spatially distributed sensor platforms that wirelessly communicate with each other. This amorphous architecture is unique since it is both synchronous and router-free, making it distinct from the more typical TCP/IP-like network schemes. A node as a physical platform for a sensor can be orbital or terrestrial, fixed or mobile and might even have real time accessibility via the Internet. Node-to-node communication is both omni-directional and bi-directional where each node sends out collected data to every other node in the network. Hence, the architecture allows every node to know what is going on with every other node throughout the sensor web at each measurement cycle. The individual nodes were all hardware equivalent [4] and Delin's architecture did not require special gateways or routing to have each of the individual pieces communicate with one another or with an end user. As a result, on-the-fly data fusion, such as false-positive identification and plume tracking, can occur within the sensor web itself and the system subsequently reacts as a coordinated, collective whole to the incoming data stream. For example, instead of having uncoordinated smoke detectors, a sensor web can react as a single, spatially dispersed, fire locator.

Right now, the term "sensor web" has morphed into many other forms not merely restricted in particular architecture, platform, frame, function and sensing mode. There are varieties of newly introduced architectures and platforms in use, the sensing mode expand as well. Thus, the “collaborative sensing”, basically means using different types of sensors (traditional wireless, mobile phones, etc.) with different communication standards to work collaboratively, which avoid traditional sensor web’s defect to build a more wider, specific, high efficiency and flexible sensor network.

SYSTEM DESIGN:

The high level architecture of the proposed system is shown in Figure 1. All the peers are connected through the P2P network. We define two types of peers in our design, the Base Peer (BP) and the Service Consumer Peer (SCP). The BP provides the necessary services and the SCPs simply view/receive the provided services. By service we mean taking images and/or other sensory information, analyzing the collected sensory information in the BP using some intelligent algorithms, and finally sending this sensory information to the SCPs to take further action(s) necessary. There might be a number n of BPs according to this architecture. Each BP is in wireless contact with several mobile robots. Each robot is equipped with several sensors and can also communicate with other robots. Consequently, the goal of this P2P architecture is to provide scalability by the introduction of new peers without the need to restart or reboot the environment and to support fault tolerance, since a defect of a peer no longer affects the functionality of other peers. In fact, SCPs can switch among one or more BPs in order to get the sensory information of the respective sites. Now we elaborate each subsystem in detail.

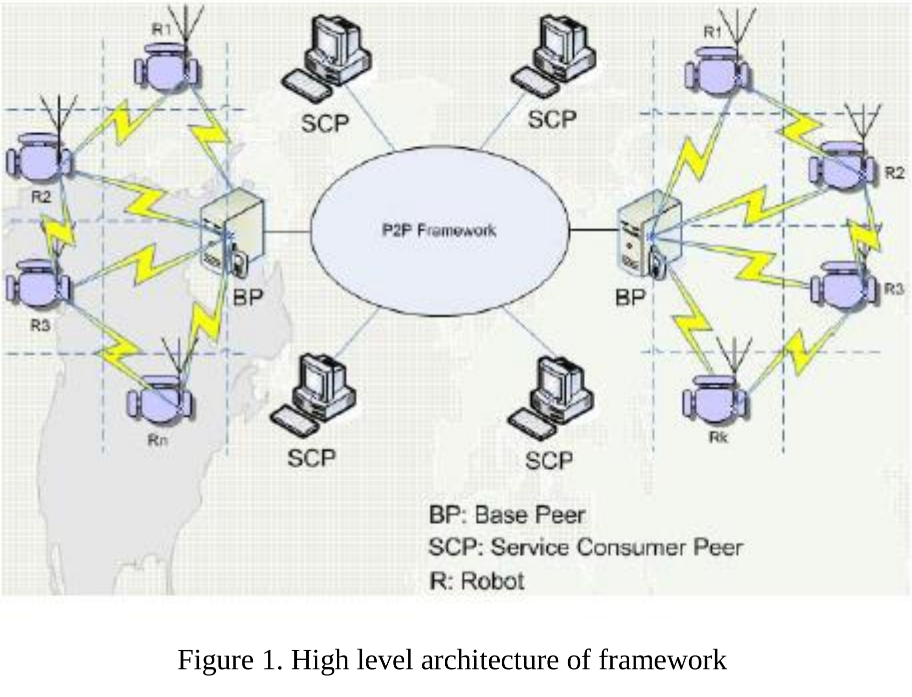

Figure 1. High level architecture of framework

ARCHITECTURE:

There are many new architecture of wireless sensor network introduced recent years and the WSNs have been widely deployed for habitat monitoring, structure monitoring, fire detection and object tracking applications. Although the traditional WSNs can provide continuous sensor readings based on a number of small and resource-limited stationary sensors carefully deployed at fixed locations. The battery and network lifetime are of great concern, given that the wireless sensors are not regularly charged or frequently maintained by human beings [5].

Thus, to be a potential powerful information source, mobile sensors have been suggested to be utilized as sensors in various participatory sensing campaigns., research work such as participatory sensing[6][7] and urban sensing[8] [9] have attracted increasing attention. A mobile sensor can be any mobile device capable of supporting the sensing tasks for a specific application. For example, they can be sensors mounted on vehicles for sensing different aspects of air qualities or detecting various types of NBC agents, sensors to monitor road and traffic conditions, or regular mobile phones or other regular mobile devices that can collect a broad range of information. It is important to note that regular mobile phones can be a powerful sensor for network information without implementing any special hardware and software, since many mobile phones are equipped with various sensing capabilities nowadays, such as noise, motion, location sensors, etc. Additionally, phones are regularly charged and used continuously, a number of participatory sensing applications (APPs) have also emerged in recent years.

Depending on whether the movements of the mobile devices can be controlled for the purpose of accomplishing a sensing task, we can classify the mobile devices into two categories: controlled mobile devices and uncontrolled mobile devices. Controlled mobile devices are those whose movements can be controlled to achieve a sensing task. Examples of controlled mobile devices include sensors on buses, airplanes, or hot-air balloons that travel along fixed or controlled routes. Uncontrolled mobile devices are those whose movements are random and not easily controllable for the purpose of accomplishing a sensing task. Examples of uncontrolled mobile sensors include sensors mounted on taxis, police cars, and people that move randomly in an area. There are several advantages of using uncontrolled mobile devices to accomplish a sensing task. For example, a large number of uncontrolled mobile devices such as taxis are usually readily available in locations of interests such as cities. Taking full advantage of the natural mobility of these uncontrolled mobiles to carry sensors around to help monitor an area can eliminate or significantly reduce the need for sending dedicated vehicles and people to achieve the same task. When carefully designed, using uncontrolled vehicles to carry sensors can also significantly reduce the number of sensors required to cover a given geographical area compared to using fixed sensors.

Therefore, one of the newly architecture is to focus on how to use uncontrolled mobiles to accomplish a sensing task collaboratively by taking full advantage of natural mobility of these uncontrolled mobile devices. This scheme highly depends on the practical testing, algorithm and routing protocol to realize the feasibility and cost effective. It has been proved that by carefully determining the number of uncontrolled mobile sensors, even though the uncontrolled sensors act autonomously, their collective actions will be able to meet the sensing objective with overwhelming probability [10].

However, although the randomness of user movements and behaviors may cause trivial negative effect, it is clear that in particular situation, we still want to get a comprehensive and certain result. Another newly introduced architecture is the collaborative sensing paradigm which utilizes both mobile phones and stationary sensors to perform sensing thus to reduce the energy consumption of stationary sensors and prolong the network lifetime. The collaboration between stationary sensors and mobile phones can provide better sensing quality, especially in case of unusual events or sensor failures in the network. The goal of this work is to provide satisfactory sensing quality adaptively to the environment change and the mobility of mobile participants. The sensing rate of stationary sensors will be reduced if there is enough sensing quality provided by the mobile participants. The sensing quality provided by the mobile phones and stationary sensors will also be adjusted adaptively to the change of the environment. Additionally, the corresponding adaptive collaborative sensing algorithm to minimize the energy consumption of stationary sensors and mobile phones, while providing satisfactory sensing quality for the system is proposed. The algorithm mainly enables mobile phones and stationary sensors to complement each other in order to achieve better overall sensing quality and reduce the energy consumption of wireless sensors. In this paradigm, mobile phones are given higher priority to perform sensing, while stationary sensors will be enabled if the required sensing quality is not reached [11].

Moreover, People are increasingly gathering contextual data (e.g. location) for their own use and are beginning to share it through systems such as Twitter and Google Latitude using mobile devices. These systems are domain specific (they are designed for a single data type) and require all users to gather their context themselves; users must install software on a device capable of gathering rich contextual data (e.g. a smartphone). The newly introduced SMOCS architecture [12] enables users with less-capable devices to offload contextual sensing and reporting to physically proximate more-capable devices; in this way, SMOCS defines a truly viral architecture. Then, using collaboration among devices that are found in the neighborhood of a mobile user to gather contextual data is practical. The density of reachable devices in any particular person's neighborhood is growing with time. SMOCS is motivated by the need to structure such collaborations to support viral growth and evolution of applications that exploit such sensing.

In this thesis, an implementation based on the SMOCS, called ContInt (Context Interleaving) also introduced. The ContInt implementation is composed of two components: Ego, a distributed social network in which users maintain personally-owned “agents”, and the ContInt plugin for Ego. The proposed SMOCS architecture enables the collection and distribution of contextual data and provides extensible interfaces to allow inference-deriving “plugins.” Thus, a more convenient, universal and flexible architecture appears.

For the P2P based Framework introduced above:

A. Base Peer Architecture

Ambient temperature, distance of detected obstacles and objects, and images are different sensory data the BP receives in real-time from each robot if accompanied with cameras. The BP maintains a FCFS (First Come First Serve) queue, receiving sensory data frames coming from different robots. The sensory data Filter Module retrieves one incoming frame from the queue, logically divides them into chunk of OCTETs, and passes each of them to the appropriate sensory data processing modules. Sensory data falls into numerous categories. Some sensory data needs only to be received from the lower layers, and be converted to high level data while some sensory data, such as image, requires to be processed using intelligent algorithms, which might be further necessary for any specific application [13].

Accordingly, we deploy two components, one is the application independent Sensory Data Processing Engine and the other one is the Application Specific Sensory Data Processing Module. To make the system deployable for any particular application, the only need part to be customized is the application specific module. The Sensory Data Processing Engine receives all the sensory data except the application specific one; if any. It decodes the binary patterns of the frame and parses them into high level sensory data. On the other hand, this component is responsible for measuring the obstacles’ and robots’ position relative to the environment as well. In this case, the BP needs some more parameters that are kept in another component called the Registry Database. The main function of this database is to keep records of each robot deployed in the environment such, for example, robot ID, the absolute geometry and co-ordinate of each block, the initial location and orientation of each robot etc. By joining the sensory data sent by a robot with its record set inside the registry, the Sensory Data Processing Engine can figure out the obstacle location relative to the test environment. After processing, this unit dispatches the following information to the Dispatcher unit: the ambient temperature and the physical location of the detected obstacle. The Application Specific Sensory Data Processing Engine is application specific and might vary from set-up to set-up. In our current architecture, we intend to use some multimedia applications such as image compression technique within the framework. Because the end-to-end communication is P2P, compressing the image data will require less bandwidth for each SCP so that any SCP having dial-up connection can even use the framework with a satisfactory data rate. Because the above two sensory data processing modules might take uneven time, the Dispatcher unit receives the high level sensory data until they all arrive, combines them, and sends them to the P2P communication layer. We have created a service layer on top of the P2P overlay network in which BPs and SCPs form a collaboration group. Each peer consists of four logical layers: 1) Collaborative Application (CA); 2) Workspace Manager (WM); 3)

Session Manager (SM); and 4) Communication Manager (CM). All of these four layers operate on top of the P2P platform, which hides the physical network lying underneath it. Due to the fact that we designed the BP to run without any human operator, it does not need the CA and the WM layers. A BP needs only the SM and the CM layers. However, each SCP needs all the four logical layers in order to receive the necessary services.

### B. Robot Positioning System

In order to define the robot's instantaneous position, we first describe how a robot calculates the distance it traveled and its angular rotation. The distance traveled can be easily measured by using some physical parameters of the robot's wheel and encoders which are associated to their respective driving motors, such as their radius, gear ratio, sensitivity, etc. The next level of positioning to be considered is to identify the robot's position with respect to the environment under surveillance. Before defining such a positioning system, we need to take into consideration the geometry of the test environment. In this research work, we have chosen the Multimedia Communication Research Laboratory (MCRLab) and the Machine Intelligence, Robotics and Mechatronics (MIRaM) Laboratory at the University of Ottawa as the virtual target environments. Although we logically divide the lab spaces into six blocks (Figure 2), the architecture is not limited to the geometry of the blocks. Every block i is defined by two corner points $(X_{is}, Y_{is})$ and $(X_{ie}, Y_{ie})$. We also define the initial position and orientation of a robot inside a block by $(X_{start}, Y_{start}, \theta_i)$.

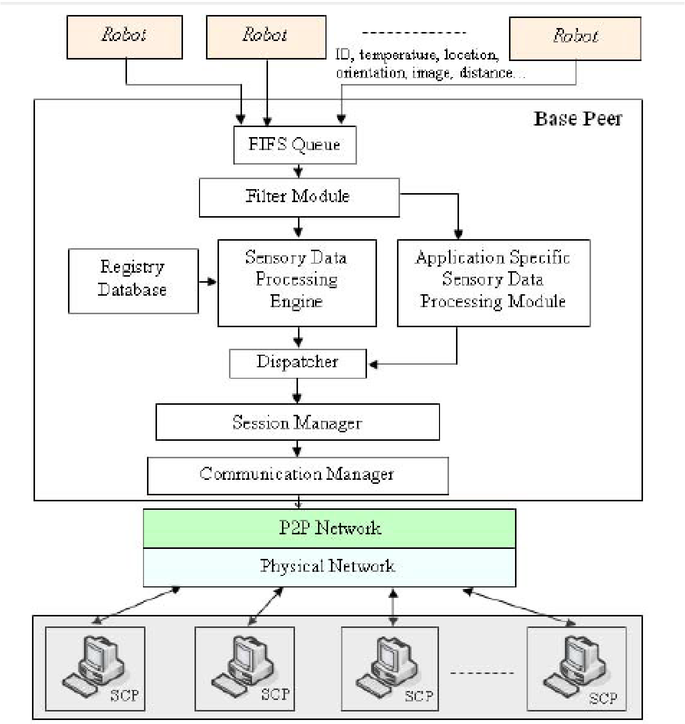

Figure 2. Base Peer (BP) components

### C. P2P Service Oriented Framework

We assume an image capturing application to facilitate the explanation of the framework. The image that the BP wants to send to SCPs is first compressed and then transformed into byte arrays. In turn the byte arrays are passed through multicast sockets, which convert the byte arrays into output streams that eventually use the P2P network for transportation. To send an image stream to N peers simultaneously, the CM layer uses N sockets to multiplex the image stream. At the receiver end, the dedicated socket receives the stream and generates a byte array, which in turn is passed to the transformation engine to reconstruct the compressed image object. The image rendering module decompresses the image frame to render it in the Graphical User Interface (GUI). The location information of obstacles is similarly sent by the SM layer of the BP as an uncompressed message through the socket, which is finally received by the CA layer of an SCP. The location renderer then simply draws a virtual 2D space based on the geometry of the remote site and points the obstacle in that space. Other sensory data, such as temperature for instance, can be similarly sent by the BP and received by the CA layer of the SCPs to render them to the appropriate location in the GUI.

### D. P2P BASED COLLABORATIVE SENSING

In fact, many mature technologies can also be integrated into our new collaborative sensing scheme. There is a paradigm recently introduced that we can make use of P2P protocol with massive personal computer to generate large coverage disaster warning system [14]. For example, earthquake is one of the most disastrous nature threats and it killed more than two million people during the twentieth century. Even a warning short before the event could reduce the casualties significantly. If there are ten seconds left, people could leave small buildings or move below a desk, which significantly reduces the risk or a lethal injury. The chance to open this small time window is to have earthquake detectors just at any place where people live and these detectors are people’s computer systems. It is a matter of fact, that personal computer systems get more and more sensing capabilities, including a microphone, a camera, shock detectors for hard disc protection, acceleration and position detection e.g. for game control, temperature and fingerprint sensors, and continuously more. The data extraction should work with a cooperative P2P network. P2P networks are well known for tasks like file sharing, telephony and other user communication applications. The power of P2P is not exhausted by this application. On the contrary, P2P’s nature advantages such like: easy to install and configuration, all the resources and contents are shared by all the peers, more reliable as central dependency is eliminated, no need for full-time System Administrator and over-all cost of building and maintaining is comparatively very less make it very suitable for building this kind of warning collaborative sensing network.

## INFORMATION QUALITY:

Due to limited network resources for sensing, communication and computation, information quality (IQ) in a wireless sensor network (WSN) highly depends on the algorithms and protocols for managing such resources. For target tracking application in WSNs consisting of active sensors in which normally a sensor senses the environment actively by emitting energy and measuring the reflected energy, a novel collaborative sensing scheme was presented to improve the IQ using joint sensing and adaptive sensor scheduling. With multiple sensors participating in a single sensing operation initiated by an emitting sensor, joint sensing can increase the sensing region of an individual emitting sensor and generate multiple sensor measurements simultaneously. By adaptive sensor scheduling, the emitting sensor for the next time step can be selected adaptively according to the predicted target location and the detection probability of the emitting sensor. Extended Kalman filter (EKF) is employed to estimate the target state (i.e., the target location and velocity) using sensor measurements and to predict the target location. A Monte Carlo method is presented to calculate the detection probability of an emitting sensor. It is demonstrated by simulation experiments that collaborative sensing can significantly improve the IQ, and hence the tracking accuracy, as compared to individual sensing.

## ENERGY-EFFICIENT:

As we talked above, with a rich set of embedded sensors, high possess capacity and high activity, mobile devices will be a very potential sensing resources. Another important advantage for mobile devices collaborative sensing is its power consumption. Not only the mobile devices are frequently charged, but also some newly introduced cloud-assisted collaborative sensing scheme can help to reduce sensing energy consumption for mobile phone sensing applications as well. Minimum energy sensing scheduling problem was defined and a polynomial-time algorithm to obtain optimal solutions was presented [15], which can be used to show energy savings that can potentially be achieved by using collaborative sensing in mobile phone sensing applications, and can also serve as a benchmark for performance evaluation.

The simulation results based on real energy consumption (measured by the Monsoon power monitor) and location (collected from the Google Map) data shows that collaborative sensing significantly reduces energy consumption compared to a traditional approach without collaborations, and the proposed heuristic algorithm performs well in terms of both total energy consumption and fairness.

## CONCLUSION:

Based on the related research, we clearly realized that different types of collaborative sensing in different platform, protocol will make sensor networks more diversification, powerful, energy efficiency and suitable for different situation. Right now, in our project, we are trying to use p2p in collaborative sensing, specifically, for real-time monitoring of high bandwidth sensors like camera video, voice, health-related sensors. There is also the need for distributed heterogeneous sensor scheduling which could use p2p. Present implementations have only the client-server mode and a p2p mode would be an additional feature with many advantages and useful in extending capabilities as above chapter explained. It would be a real-time monitoring of high bandwidth sensors in collaboration with P2P protocol.

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