BonnSens: A Mesh-based Command and Control Sensing System for Public Safety Scenarios

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I. Motivation

Tactical and mission critical networking in public safety scenarios is strongly emerging. In these scenarios, different kind of sensor information, e.g. GPS, vital, and environmental data, needs to be transported from mobile units over a wireless network to a centralized command point in order to increase situational awareness. Hence, for command and control robust communication networks are required.

These networks must be reliable even when all infrastructure has been destroyed. Wireless multi-hop networks are supposed to meet the requirements of spontaneous deployment, independence of any kind of existing infrastructure, and robustness in the sense of self-organization and self-healing by their very definition. These networks have been a topic in research for more than a decade now. Recently, real-world tests and deployments provided valuable insights concerning challenges and future research directions and enable the research community to run tests in static real-world networks. However, concerning public safety requirements, these testbeds lack significant aspects: No spontaneous deployment, no or at least no mobility typical for public safety, and no typical applications and traffic. Due to these characteristics, developing algorithms and protocols for these scenarios as well as deploying public safety networks is a huge challenge.

To overcome this challenge, we developed *BonnSens* a prototype based on commercial off-the-shelf (COTS) hardware. The prototype comprises typical public safety applications and is spontaneously deployable. Furthermore, this prototype enabled us to perform on-site evaluations with real public safety end-users by deploying the prototype in disaster area maneuvers. In our demo, we will demonstrate our COTS-based prototype.

II. BonnSens Architecture

The *BonnSens* architecture consists of a distributed sensor and collector application for the transmission of sensor data over a wireless multi-hop network as shown in Fig. 1. The sensing application supports the gathering of sensor information via modular extensible plugins. A special transport protocol is used for the transmission of sensor data which is processed and visualized subsequently by the collector on the server side.

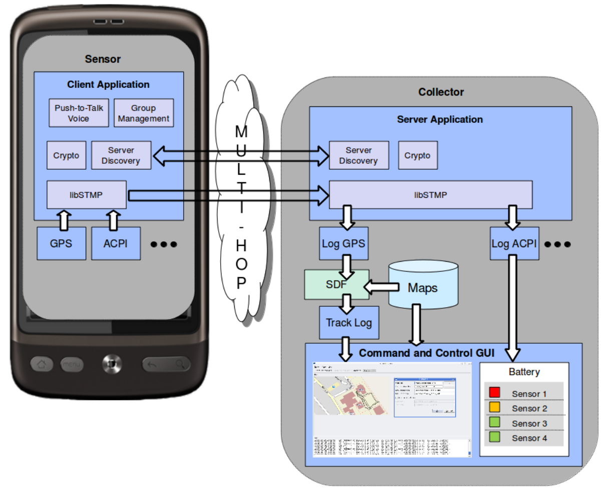

Fig. 1. *BonnSens* System Architecture.

The *BonnSens* framework is under BSD license and has not been published yet. It consists of two hardware components: (1) portable, lightweight sensing nodes and (2) fully-equipped collector nodes. For the sensing nodes, we have implemented a client sensing application for Android OS and use standard smartphones (currently the Samsung Galaxy Nexus i9250) since many smartphones on the market today are equipped with integrated sensors like GPS, accelerometer, and compass and also come with an IEEE 802.11 wireless network interface. For the collector nodes, standard COTS laptops can be used. All nodes (lightweight and fully-equipped) are routers at the same time. However, to have a more robust network and to safe energy at the lightweight nodes, we add a mesh backbone consisting of two kinds of COTS mesh routers with Atheros WiFi-cards (TP-LINK TL-WN660G), namely the ASUS WL-500g Premium V1 and the ALIX 3D2. Both enable us to tether the UMTS network if available. The routers are powered by motorbike-batteries with 12V-20Ah in order to facilitate an easy on-site spontaneous deployment for more than 12 hours.

A. Ad-hoc Routing Protocol

We chose the reactive mesh-based On-Demand Multicast Routing Protocol (ODMRP) [5] for routing as it showed promising results in public safety specific simulative performance evaluations [2]. We implemented ODMRP using the

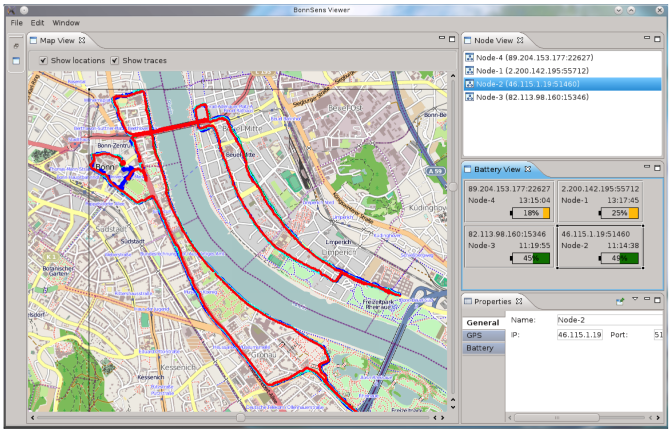

Fig. 2. Situational awareness – screenshot of the tracking GUI.

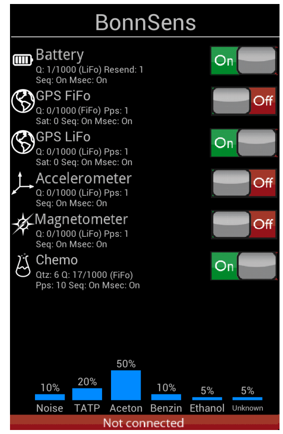

Fig. 3. Screenshot of the *BonnSens* client application for Android.

Click modular routing framework [4] which enables us to run ODMRP on the mesh routers as well as on Android phones. Moreover, since the quality of wireless links in real deployments turned out to be extremely variable, unpredictable, and asymmetric, we take these characteristics into account by using a routing metric estimating the link quality based on the *hello messages* received.

B. Sensor Data Transmission and Management Protocol

To provide a common framework for the transport of sensor data and for basic functionality such as registering at a receiver, timestamping of sensor data, and synchronization of all nodes, we specified and implemented the Sensor Data Transmission and Management Protocol (STMP) [1]. In order to realize a consistent implementation of STMP for lightweight as well as for collector nodes, we modularized STMP by implementing it as a commonly usable library in C named *libSTMP*. Client applications may thus be programmed either using the Android API for the smartphones or using native C code for the deployment on a laptop, both accessing the same library.

C. Command and Control Server

On the server side, we implemented a command and control server application using *libSTMP* for receiving sensor data from the clients and for writing it to a database. This data, in particular location information, needs to be filtered and fused. Therefore, we integrated appropriate sensor data fusion algorithms operating directly on the database in order to provide accurate tracking. In our case, a standard Kalman filter is not able to include out-of-sequence measurements. An Accumulated State Density (ASD) methodology [3] which allows for the processing of unordered measurements thus proved to be a valuable alternative. For situational awareness, among other sensor data, the clients' tracks can be displayed using a tracking GUI, as depicted in Fig. 2.

D. Android Sensor Data Client

BonnSens currently supports the gathering and transmission of battery, GPS, accelerometer, and magnetometer data as well as neighbor metric data from ODMRP. Each sensor at a client can be enabled separately using our sensor data client application, as shown in Fig. 3. On activation, a client creates an STMP sensor data association with the server by registering its active sensors. Several configurable options are available for each sensor like rate control or the usage of a LIFO queuing scheme instead of the standard FIFO queue.

In addition to the on-board sensors of the smartphone devices, it is possible to connect further sensors with the smartphone via its USB interface and to process their data. For instance, we have integrated a chemical sensor prototype based on quartz crystal microbalances (QCM) allowing to detect hazardous materials or buried persons in disaster areas.

III. Demo Setup

We will demonstrate the *BonnSens* command and control sensing system with its main components. In a real deployment, the audience is able to interact with android smartphone devices transferring sensor data to the command and control server and to experiment with the tracking GUI. Moreover, using our chemical sensor prototype, we will show the state of the art of hazardous material detection.

References

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