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A Cross Layer Fault Tolerant Communication Architecture for Wireless Sensor Networks

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Abstract: A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. Routing is a key feature for wireless sensor networks, as it extends the geographic range, enables larger installation and Provides redundancy to packet transmission. In order to manage faults in wireless sensor networks a new routing protocol and integrated MAC is used. Protocol design uses cross layer principle to minimize signalling overhead and power consumption. By using different routing protocols for cluster architecture, the efficiency and data latency has to be analyzed. The proposed robust communication architecture, for fault tolerant communication support for emergency application with WSN.

Key words: Signalling overhead and power · Such as temperature · Sound · Vibration

INTRODUCTION

The challenges in the hierarchy of detecting the relevant quantities, monitoring and collecting the data, assessing and evaluating the information, formulating meaningful user displays and performing decision-making and alarm functions are enormous [1]. The information needed by smart environments is provided by Distributed Wireless Sensor Networks, which are responsible for sensing as well as for the first stages of the processing hierarchy.

Remote sensing and measuring is becoming more important with accelerating advances in technology. It has ascended from meter reading to data acquisition systems to a new era of wireless sensor networks. Installation and maintenance of these systems are costly. These systems are inflexible once installed and require great amount of expertise from installer.

This method was both inefficient and error prone because being a monotonous task it was difficult for humans to perform well over an extended period of time [2]. Next generation belonging to data acquisition systems automated the recording by wiring sensors to a central data storage unit.. Wiring of these systems even makes them infeasible in certain situations. Wireless sensor networks are now providing an intelligent platform to gather, analyze and react on data without human intervention. Typically a sensor network consists of autonomous wireless sensing nodes that organize to form a network. Each node is equipped with certain accessories which enable them to sense, monitor and transmitting data wirelessly. These nodes are capable of communicating with other nodes and passing their data to a base station where data will be compiled, analyzed, processed and reacted upon. Base station forms the link between sensors and higher-level application.

Sensors in these multi-hop networks detect events and then communicate the collected information to a central location where parameters characterizing these events are estimated. Since the cost of transmission is higher than processing, it may be advantageous to organize the sensors into *clusters*. In the clustered environment, the data gathered by the sensors is communicated to the data processing center through a *hierarchy* of *cluster heads* (CHs) [3]. In this paper, robust communications architecture, providing a fault tolerant communications support for emergency applications with WSNs, is proposed. Despite more complex solution

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have been proposed in the literature, the adopted approach combines effectiveness and easy implementation in real user. Since the main parameters to be optimized are both the message delivery and reconfiguration latencies, the investigated solution adopts a *tiered architecture*.

In particular, a two tier topology is applied to enhance scalability and efficiency of the communications protocols. According to it, once a cluster has been established through a *set up* procedure, ordinary nodes (ONs) are continuously monitored by their own CH that is also in charge of remote data delivering [4]. Whenever a link quality degradation is detected, a warning is sent to the decision making system. If the problem still occurs due to an *abnormal* operative condition, the involved ONs are assumed to be definitely lost and an alarm is remotely delivered, suggesting the presence of a malicious attack1. Finally, CH is able to manage an *orphanage* procedure to recover ONs lacking of their original CH, which has been irreparably damaged. However, if no CH is available, a group of ONs jointly adopts a *multi-hop* routing strategy, setting up a sort of ad hoc network to reach anyway the remote server, according to a cross-layer design.

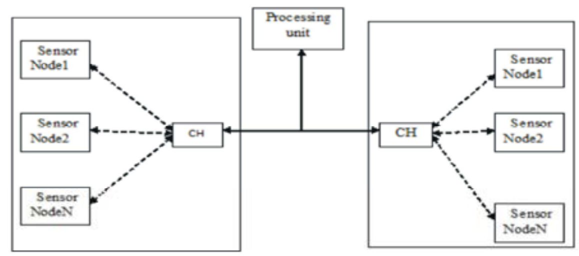

Fig. 1: Two Tiered Architecture

Network Topology

Two-tiered Architecture: While low energy consumption has been considered as the most predominant requirement in the design of wireless sensor networks, supporting real-time communications is nonetheless increasingly important. In fact, a sensor network typically interacts with a physical environment, thus, it has to meet timing constraints. Time requirements are generally in the form of end-to-end deadlines of sensory data packets from sensor nodes toward a control station.

The primary real-time requirement is guaranteeing bounded end-to-end delays or at least statistical delay bounds. Many approaches have dealt with providing delay bounds in a multihop sensor network. This has been basically achieved by means of Medium Access Control (MAC) protocols such as LEACH, D-MAC and DB-MAC, which guarantee that every node gains medium access rights within a bounded time interval. Other solutions have targeted the Network Layer protocols to support real-time communications, such as SPEED.

These underlying approaches are promising and offer significant improvements on the real-time performance in sensor networks by guaranteeing soft delay bounds. Nonetheless, those delays may turn out to be too high due to the limited networking capacities of sensor nodes, resulting from the severe energy constraint and the low data rate [5].

The, end-to-end delays can get higher when increasing the number of sensor nodes, due to a higher number of intermediate hops needed to reach the destination. Therefore, increased delays may result from a larger geographic area, where more scattered nodes are needed to cover the monitored region.

To prevent long end-to-end delays in large-scale wireless sensor networks, we investigate the potential use of a two-tiered sensor network architecture, where a wireless sensor network is supported by a Wireless Local Area Network (WLAN), offering more powerful networking capabilities. The WLAN layer will be involved in the communication between the sensor network and the control station, mitigating the impact of the limited capacities of the sensor nodes. With this two-tiered architecture we target to provide more reliable data delivery with reduced delay bounds and lower energy consumption in the underlying sensor network, thereby increasing its lifetime. At this moment, we are focusing on the technical specification of the two-tiered architecture. Moreover, we intend to evaluate the cost-effectiveness of our approach with reference to a basic wireless sensor network [6].

Our work consists in defining scalable, reliable, real-time and energy-efficient communication and coordination schemes in the design of a two-tiered sensor network architecture, in a cost-effective way. This network is composed of a low data rate, short transmission range, energy-constrained large-scale sensor network supported by an overlay WLAN, which has more suitable capabilities, including high data rate, large transmission range and sufficient energy resources, to ensure real-time communications. In this paper, we denote the routing devices of the WLAN layer as *access points.*

This two-tiered network will definitely improve the network performance in terms of real-time, reliability and energy consumption. Real-time improvement will be achieved by the grant of higher bandwidth and long transmission range in the WLAN layer resulting in lower hop count to reach the destination [7]. Also, since WLAN access points are supposed to be more reliable than sensor nodes because they have potent communication capabilities, the communication reliability will be consequently improved, reducing the number of lost/erroneous packets (e.g. due to a sensor node failure or mobility).

Cluster Head Node: its main task consist in coordinating the nodes belonging to its own cluster, collecting the data samples and forwarding them to the remote server together with providing bidirectional commands (ping, node description, battery level request) and alarms. CH is endowed with two different air interfaces, acting as a gateway. It plays a crucial role in network building, maintaining and recovering and to reduce network load by adopting data fusion algorithms [8].

Ordinary-node: An ON carries out the monitoring of a particular spatial area it is responsible for and then transmits data with a secure approach.

Remote Server: Even though it does not make part of WSN, it has the function to storage, process and display data to the remote user in a suitable way

Cluster head Selection using AHP: In the hierarchical network architecture, WSN is divided into several clusters. In each cluster, one special node acts as cluster head (CH) which collects and compresses the data sent by common nodes within that cluster and then transmits the processed data to BS. Once CH is destroyed by accident or drained for the above heavy communication load, it is no longer operational and all common nodes belonging to that cluster lose communication ability. The increasing invalid CHs become the bottleneck of the whole WSN and shorten the network lifetime. Apparently, CH plays an important role in WSN. Thus an appropriate cluster head selection approach is needed.

- BS broadcasts an inquiry request message (Inquiry- REQ) using a non-persistent CSMA MAC protocol [12]. This massage is a short message, consisting of the number of clusters.
- On receiving Inquiry-REQ, each node responds with current information messages (CInform), including its basic information, e.g. node's ID, node category, node velocity etc. This message is much longer than Inquiry-REQ.

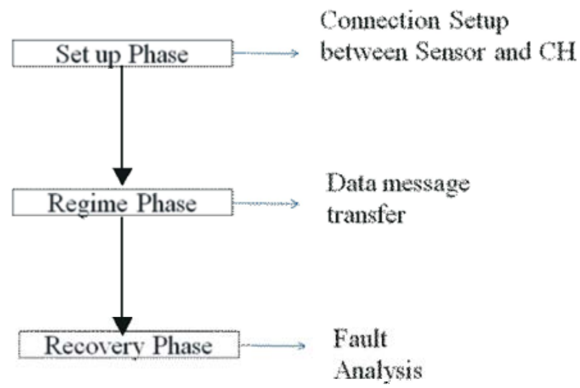

Fig. 2: System Flow Model

- According to the collected Cinform messages, BS makes a decision to choose appropriate CHs using the AHP algorithm in a centralized fashion.
- BS broadcasts a notification message (NTF). It is again a small message containing a list of CH's ID.
- Once a node e.g. node *i* finds its ID in the list, node *i* is notified to become CH for the current round

System Flow Model: In this System flow model there are three phases, They are

- Setup Phase
- Regime Phase
- Recovery Phase

Setup Phase:

- In this selected CH broadcast an ADV message.
- This message contains each CH's ID and a header that distinguish this message as an announcement message.
- On receiving the ADV message each node will send a join REQ message to the CH
- On receiving join REQ, each CH broadcast a MEM(member message) including the list of its cluster member.

Regime Phase:

- Regime phase begins once the set-up phase is completed.
- In this ON are able to transmit data message to their CH.
- Additional packets are also sent to monitor the status of the link.
- Both a short and long term periodic evaluation is delivered to remote server.

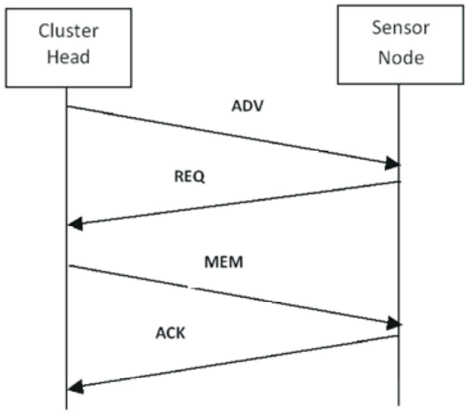

Fig. 3: Setup Phase

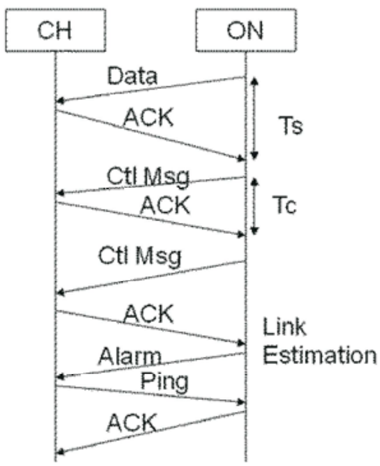

Fig. 4: Rigime Phase

- For a purpose of reliability each message is ACK.
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Recovery Phase:

- For the purpose of Fault tolerance, a recovery phase is needed.
- When the CH is damaged, the ON associated with damaged CH are called as *orphan ON.*
- Orphan ON is associated with another CH in a direct or indirect way.
- Direct way needs link-to-link path. It will takes place at layer 2.
- Indirect way needs multi-hop routing solution. It will takes place at layer 3.

Simulation Result: In Network Simulator the cross layer fault tolerance architecture for energy saving and the network status is to be simulated. In prior to the simulation 10 sensor nodes are formed and the

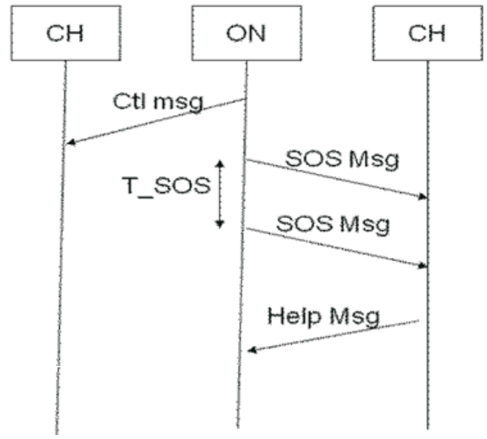

Fig. 5: Recovery Phase

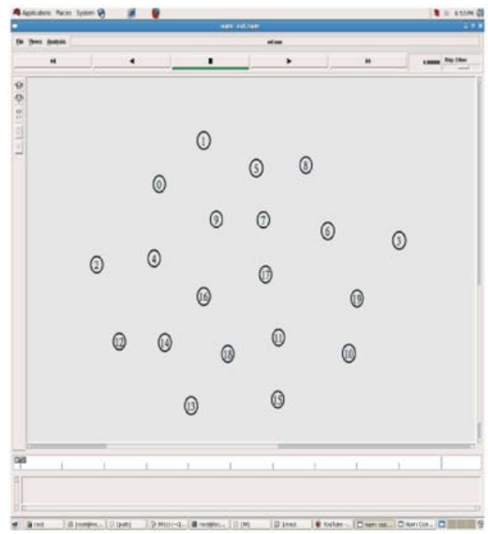

Fig. 6: Formation Of Sensor Node

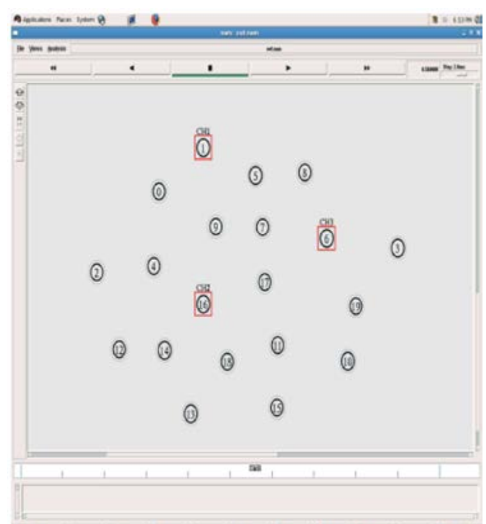

Fig. 7: Cluster head Selection

corresponding cluster head are chosen are shown in Table 1 and its animated output is given in (Fig 6) and (Fig 7).

In Network Simulator ten sensor nodes are created by setting the CBR (constant bit rate) as a traffic and attaching the UDP as a agent to the sensor node. According to the distance vector routing protocol. Some of the sensor nodes are selected as the clusters head for the packet transmission.

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