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Smart Sensing and Context

First European Conference, EuroSSC 2006
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Preface

This volume contains the papers and posters selected for presentation at the First European Conference on Smart Sensing and Context (EuroSSC 2006) in Enschede, The Netherlands. EuroSSC 2006 was the first conference of a series aiming at bringing together designers, engineers and researchers to explore two complementary viewpoints:

– A device-centric, technology-driven view: concerning intelligent sensors, sensor networks and information processing for a new generation of networked devices and environments.
– A service-centric, user-driven view: exploring architectures, techniques, and algorithms for context-aware and pro-active applications made possible by the diffusion of ambient communication, cooperating objects, and interaction technologies.

These subjects are active and relevant research areas in themselves, and there are several conferences that address them separately. EuroSSC 2006, however, considered them both, and especially the symbiosis between them, which we expect to result in very inspiring and interesting discussions, as well as new research ideas on how to combine them.

The conference was organized in single tracks covering various issues ranging from intelligent sensors, sensor networks, context management and context awareness, and privacy, to applications and test beds. Organizing a conference for the first time requires lots of preparations, such as finding a publisher, sponsoring organizations, and TPC members and most importantly attracting potential submitters. Fortunately, the amount and quality of the submissions were such that we were in the luxurious position to be able to accept only high quality and relevant papers. The conference attracted world wide attention and submissions came from five continents. A total of 15 accepted full papers and 14 accepted posters came from Asia, North America and Europe. All full papers underwent peer blind reviewing by at least three reviewers, and were judged based on their novelty, technical quality, account of prior work, readability and relevance. The acceptance rate for full papers was 27%. Poster descriptions were reviewed by two referees and accepted posters appear as short papers in the proceedings.

The technical program was complemented by interesting keynotes from Anind Dey and Kevin Warwick, titled *End-User Control in the Smart Home*, and *Upgrading Humans' Technical Realities and New Morals*, respectively. Besides papers, posters, and keynotes, the technical program also included a debate on the social and economical impact of ambient technology.

The EuroSSC 2006 conference was technically co-sponsored by the IEEE Communications Society and supported by the Ministry of Economic Affairs of the Netherlands through the Smart Surroundings, Freeband, and MultimediaN projects, the European IST funded e-SENSE project, Ambient Systems B.V., CTIT, and was organized in cooperation with EuSAI and ISSNIP.

Apart from the above listed organizations and projects, we would also like to express our gratitude to the many individuals who contributed to organizing EuroSSC 2006 and offering technical and administrative support. Specifically, we want to acknowledge the TPC members, additional referees, LNCS staff, and keynote speakers for their contributions.

August 2006

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Posters: Short Papers

Multi-channel Support for Dense Wireless Sensor Networking

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Abstract. Currently, most wireless sensor network applications assume the presence of single-channel Medium Access Control (MAC) protocols. When sensor nodes are densely deployed, single-channel MAC protocols may be inadequate due to the higher demand for the limited bandwidth. To overcome this drawback, we propose multiple channel support for improving the performance. Our method allows the nodes to utilize new frequency channels which results in the significant increase on the number of nodes that are granted access to the wireless medium. The method requires only one half-duplex transceiver per node, which is capable of sending and receiving over distinguished frequency channels. Simulation results show that, method successfully utilizes multiple channels and increases the performance proportional to the number of available frequencies for an example single-channel MAC protocol, LMAC.

1 Introduction

Wireless Sensor Networks (WSN) [1], is an evolving technology that is the fundament of various ubiquitous applications. WSN is embedded into the real world and enables monitoring, inspection and analysis of unknown, untested environments with battery operated, tiny sensor devices. Sensor nodes are designed to collect sensor data about the context and to transmit the readings by wireless communication.

With the growing interest, in the near future, WSN will be deployed everywhere in large numbers, which may be of the order of hundreds or thousands and even more [2]. The underlying protocols must be able to deal with these numbers of nodes. In a dense network, demand is higher for the limited bandwidth. This results in less chance to access the wireless medium due to higher contention in a dense neighborhood[1]. Besides the large numbers, limited channel capacity and the influence of interference due to external networks or electronic devices, that share the same parts of the spectrum, will result in a competitive communication environment.

[1] We define the neighborhood of a node as the set of nodes which are located within the node's transmission range. We consider a dense network where a node -on the average- has more than 50 nodes in its neighborhood.

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The important reason for this competition is that sensor nodes share a single channel[2]. If the transceiver equipment used for wireless communication is able to operate on multiple non-overlapping channels rather than a single channel, multiple transmissions can take place on the wireless medium without disturbing each other. This leads to lower contention, less collisions and retransmissions. Today's transceiver hardware, which is used for sensor nodes, supports operation on multiple frequencies. For example, the radio used by Ambient μNode [3] and CC2420 radio [4] for MICAz and Telos sensor nodes can be tuned to different channels.

We consider the LMAC protocol [5],[6] as an example to show the inefficiency of single-channel MAC protocols in densely deployed sensor networks. LMAC is a light-weight and energy efficient MAC protocol proposed for WSN. It is based on the concept of scheduled access to the wireless medium. Each node controls a timeslot to transmit its data. Timeslots are selected in a distributed, self-configuring way. Further details of the LMAC protocol will be given in Section 3.

Besides its advantages, LMAC's operation depends on the number of timeslots, and in turn on the density of the neighborhood. When all timeslots are exhausted, the node may not be able to access the wireless medium and remains in its initialization state to find an empty timeslot. As the neighborhood gets denser, the number of required timeslots grows rapidly. Therefore, we need a mechanism that reduces the contention in the neighborhood and allows a node to control a timeslot for transmitting its data.

We propose to multiplex the timeslots with the frequency domain for using the spectrum more efficiently. Note that this approach does not use different transceivers; instead one half-duplex transceiver is sufficient. The proposed method allows the nodes to switch their transceivers on new channels on-demand, if the network reaches a density limit. One may argue that switching to different channels by a half-duplex transceiver will cause disconnections in the network. However, our method optimizes connectivity, i.e., connects as many neighbors as possible via multiple channels.

The method is composed of two phases. In the first phase, nodes select timeslots according to the single-channel LMAC rules. In the second phase, nodes select timeslots and also channels to communicate on. The LMAC protocol ensures that a timeslot is only reused after at least 2-hops. Thus, the number of timeslots that a node can select is not only limited by the number of 1-hop neighbors but also by 2-hop neighbors. However, if multiple channels are available, nodes are allowed to select those timeslots that are occupied by their 2-hop neighbors on different channels. The second phase is based on this idea of utilizing different channels by allowing concurrent transmissions.

The rest of the paper is organized as follows: Section 2 summarizes related work. Section 3 introduces the LMAC protocol. Section 4 describes the multi-channel support for LMAC protocol. Section 5 reveals the performance of the method by experimental simulations. Section 6 discusses some concluding remarks and suggestions for future work.

---

[2] A channel is defined to be a frequency range over which two nodes communicate. We will use the terms "channel" and "frequency" interchangeably in the text.

2 Related Work

The channel assignment problem and multi-channel MAC protocols in wireless networks have been extensively studied. Usage of multiple channels in multi-hop ad hoc networks has been shown to increase the throughput considerably, by allowing concurrent transmissions on different non-overlapping channels [7], [8], [9], [10], [11], [12]. Details about the algorithms and comparisons are explained by Mo et al,. [13].

When we look into WSN domain, characteristics are quite different from the ad-hoc networks. A typical sensor device is usually equipped with a single half-duplex radio transceiver, which can not transmit and receive simultaneously, but can work on different channels separately. On the other hand, traditional wireless ad hoc networks usually assume more powerful radio hardware and multiple transceivers per node. For instance, typical bandwidth used by WSN is usually very limited (e.g., 50Kbps). Zhou et al. [14] showed why multi-channel MAC protocols which are based on IEEE 802.11 are not suitable for WSN with respect to the packet size, RTS/CTS mechanism and limited bandwidth. We show why single-channel MAC protocols are not efficient in densely deployed sensor networks, for an example single-channel MAC protocol.

Zhou et al., [14] recently introduced the MMSN multi-frequency MAC protocol especially designed for WSN. MMSN consists of two aspects: frequency assignment and medium access. In frequency assignment, each node is assigned a frequency for data reception. Hence, a node intending to transmit should know about the receiver's frequency. Broadcast packets are transmitted on a dedicated channel. Medium access is a combination of contention and scheduled operation. Our method is not a complete MAC protocol proposal, but it provides multiple channel support for an example single-channel MAC protocol: Timeslots are multiplexed with frequency domain on demand, if the number of timeslots in the neighborhood is exhausted on a single channel.

IEEE 802.15.4 standard [15] also provides multiple channels for Personal Area Networks (PAN). The idea is to use non-conflicting channels to identify different PAN's. This is different than our approach where we introduce multiple channels in a dense network when the demand for the limited bandwidth is higher.

3 The LMAC Protocol

LMAC [5] is an energy-efficient medium access protocol designed for WSN. The protocol enables the communicating entities to access the wireless medium on a time-scheduled basis over a single frequency channel. Time-scheduled method has a natural advantage of collision free medium access, which avoids wasting energy and time.

Like other time-scheduled MAC algorithms, LMAC also considers time to be divided into slots which are further organized into periodic frames. A node with the intention to transmit can take control of a timeslot. A node transmits a control message at the beginning of its timeslot to address the receiver nodes.

Neighbor nodes must always listen at the beginning of a timeslot which contains information about the intended receivers, synchronization and the current timeslot. If neighbor nodes discover that they are not the intended receivers they turn off their power-consuming transceivers.

The timeslot selection mechanism in LMAC is fully distributed, thus needs no base-stations or central authorities to decide and allocate the timeslots to the nodes. In addition, the multi-hop nature of the WSN allows the timeslots to be reused.

For timeslot selection, the nodes use an algorithm based on local information only. Each node maintains a vector of length equal to the number of timeslots. This vector is used for storing the occupied slots within the 2-hop neighborhood. Initially, the vector is cleared. Nodes transmit information in the control message about those timeslots that the node considers to be occupied by itself and its 1-hop neighbors. When a packet is received, the logical OR operation is executed to update the information about the occupied slots in the neighborhood and the information is stored in the vector. If a node is not yet controlling any timeslot, it selects one from the free slots. This method ensures that a timeslot is only reused after at least 2-hops. The distributed algorithm for timeslot selection is shown in Figure 1. The node marked with "?" is searching for a timeslot and other nodes control the timeslots they are marked by. It receives the occupied slots information from the neighbors, executes the OR operation and finds timeslot 7 as free and grabs it.

When there are no more free slots (i.e. in a dense neighborhood), the node remains in its initialization state, periodically monitoring frames to find an empty timeslot. Reserving a timeslot for each node or increasing the number of timeslots

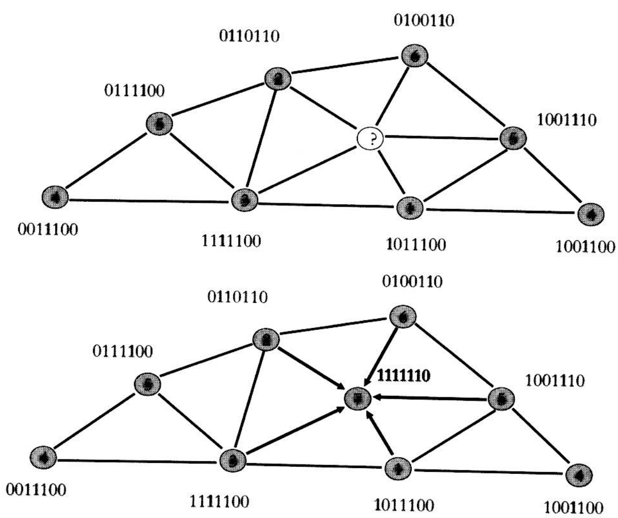

Fig. 1. LMAC Protocol: Timeslot selection

in the network may be a possible solution. However, this would increase the latency of communication and time of waiting, before nodes get the opportunity to transmit. For this reason, the frame interval should be kept as short as possible and reused as much as possible. Currently, in a typical LMAC implementation, frame length is 1 second and a frame consists of 32 timeslots.

4 Multi-channel Support for LMAC

To overcome the deficiency of single-channel LMAC protocol in dense networks, we propose an algorithm which utilizes multiple channels. Besides, the algorithm optimizes connectivity, i.e., connects as many neighbors as possible.

The algorithms is based on local information only: it does not need central authorities to decide and allocate the frequencies. For instance, a central solution for multiple channel allocation -which is also used in cellular networks or DECT- would be to let a base-station (for example a sink node which is a gateway between the users of the network and the network itself in WSN) assign the channels. The sink node could assign frequencies to its 1-hop neighbors, and frequency information can be broadcast to the remaining nodes, in a multi-hop fashion. The nodes that are receiving the broadcast messages with frequency information, switch to the associated frequency. In this approach, the ultimate view of the network is partitions communicating on different frequencies. Nodes are only aware of their neighbors which are using the same channel. If two

waste of energy and latency.

assumptions.

4.1 Design Issues and Assumptions

- N non-overlapping frequency channels are available. Nodes are aware of the number and frequency range of the channels.
- All the nodes are communicating in the basic channel (single channel) at the beginning. If timeslots are exhausted in a node's neighborhood on the basic channel, new channels are introduced.
- The switching delay from one channel to another can be neglected, e.g., for the transceiver of Ambient μNode sensor node platform, 650μsec is much less than a typical timeslot duration, 31.25msec.
- Each node has one radio interface which is a half-duplex transceiver. A node cannot both transmit and receive at the same time, simultaneously.
- To establish multi-hop time synchronization ([16], [17]), every node uses its parent node to synchronize to every frame. A node can be a parent of another node if it's closer to the sink.