Quick Data Assembly in Tree-Based Wireless Sensor Networks

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Abstract: It was examined that wireless sensor networks: networks of small devices equipped with sensors, microprocessor and wireless communication interfaces to collect the data from different sources without using wires are a technology that has gained a lot of interest lately. The broad spectrum of new and interesting applications, ranging from personal health-care to environmental monitoring and military applications, is proposed for such networks. Various wireless technologies, like simple Wi-Fi, RF, Bluetooth, UWB or infrared might be used for communication between sensors. In this paper the main principles, applications and issues of Bluetooth based wireless sensor networks, as well as an implementation of a simple Bluetooth based sensor network are described. The main problems experienced during the implementation and applied solutions are presented. We give lower bounds on the schedule length when interference is completely eliminated, and propose algorithms that achieve these bounds. We also evaluate the performance of various channel assignment methods and find empirically that for moderate size networks of about 100 nodes, the use of multi-frequency scheduling can suffice to eliminate most of the interference. Hence the data can be collected with no longer remains limited by interface finally the access is from routing trees. In the improvement of the performance we focused on the different procedures finally we evaluated the impact of interface and modules in the process. Now a day's wireless technology has become global technology specification for "always on" wireless communication not just as a point-to-point but was a network technology as well.

Key Words: Power Control, TDMA scheduling, DCS, Pico Net, TEDS, Scatter Net, LMP, Sensor

Introduction:

The communications capability of devices and continuous transparent information routes are indispensable components of future oriented automation concepts. Communication is increasing rapidly in industrial environment even at field level. In any industry the process can be realized through sensors and can be controlled through actuators. The process is monitored on the central control room by getting signals through a pair of wires from each field device in Distributed Control Systems (DCS). With advent in networking concept, the cost of wiring is saved by networking the field devices. But the latest trend is elimination of wires i.e., wireless networks. Wireless sensor networks - networks of small devices equipped with sensors, microprocessor and wireless communication interfaces. The goals of wireless units are unification and harmony as well, specifically enabling different devices to communicate through a commonly accepted standard for wireless connectivity. In recent years, the advances in wireless communication and electronics have accelerated to develop many wireless network solutions to replace existing wired networks. A wireless network solution can support mobility and flexibility of nodes in a network. Especially in sensor networks, it has many advantages to replace cables with wireless logical links. On the other hand, Bluetooth is generally considered as a promising short-range wireless technology because of its inexpensive cost, low power and small size, and thus Bluetooth has been gaining increasing interest from various industries. For the above reasons, we adopt Bluetooth technology for a wireless sensor network, which is designed for security systems. Since Bluetooth will continue to be a feature found in many devices, it is worthwhile to investigate its use in wireless sensor networks. In this paper, we describe a Bluetooth wireless sensor network for security systems, which includes the implementation issues about system architecture, power management, self-configuration of network, and routing. We think that the methods or algorithms described in this paper can be easily applied to other embedded applications for data transudation through wireless networks.

Wireless Sensor Networks: Wireless sensor networks comprise number of small devices equipped with a sensing unit, microprocessor, wireless communication interface and power source. In contrast to the traditional sensor networks that are carefully planned and deployed to the predetermined positions, wireless sensor networks can be deployed in an ad-hoc manner. Of course, such deployment requires adequate communication protocols that are able to organize the network automatically, without the need for human intervention. Beside self-organization capability, another important feature of wireless sensor networks is collaboration of network nodes during the task execution. In contrast to the traditional sensor networks where all sensor data is gathered at a server and then analysed and fused, data processing and fusion is now performed by smart nodes themselves. Each node processes raw measurement data in order to decrease amount of data sent over wireless links and forwards only relevant parts to nodes responsible for data fusion. Data-centric nature of the network is yet another specific characteristic of wireless sensor networks. As deployment of smart sensor nodes is not planned in advance and positions of nodes in the field are not determined, it could happen that some sensor nodes end in such positions that they either cannot perform required measurement or the error probability is high. That is why a redundant number of smart nodes observing the same phenomenon is deployed in the field. These nodes then communicate, collaborate and share data, thus ensuring better results (each sensor has its own view of the phenomenon – when these views are combined a better picture of the phenomenon is obtained). Having this in mind, it is more reasonable for a user to send a data request to all sensors monitoring the phenomenon than to send it to one specific sensor node. Using a multicast routing protocol to send messages to all relevant nodes would require unique addressing scheme in the network. However, due to the sheer number of sensors and user requirements (user need information about the phenomenon, does not need information about the phenomenon from a particular sensor),data-centric approach is used where sensors are designated using description of data they can provide instead of using unique IDs. Messages are directed to nodes using routing protocols that can find the route based on the data description contained in the message. Power efficiency is one of the main requirements for all protocols and algorithms used in these networks. As power resources of each node are limited and required lifetime for many scenarios is measured in months and even years, it is of paramount importance to design system in such a way to ensure power savings whenever possible.

Querying and Tasking: From the user point of view, querying and tasking are two main services provided by wireless sensor networks. Queries are used when user requires only the current value of the observed phenomenon. As wireless sensor networks are data-centric networks, the user does not query a specific node for the information it might provide, but defines data (type,location, accuracy, time, etc.) he/she is interested in and requests it from all nodes that can provide the answer. Forexample, user can look for “temperature in the north region of the observed area” or for “location of all sensors where chemical agents are present and their level is above the threshold”. Tasking is a more complex operation and is used when a phenomenon has to be observed over a longer period of time. For example, a user can ask a sensor network to detect a specific type of vehicle in the area and to monitor its movement. In order to execute the task, different types of sensors have to collaborate: seismic to detect motion, video and audio to detect type of vehicle etc. Information about the vehicle trajectory is forwarded to the user. Both queries and tasks are injected to the network by the gateway which also collects replies and forwards them to users

Gateway functionality:

Smart sensor nodes scattered in the field collect data and send it to users via gateway using multiple hop routes The main functions of a gateway are the following:

− Communication with sensor network - Short-range wireless communication is used (Bluetooth, UWB, RF, IR, etc.).Provides functions like discovery of smart sensor nodes, generic methods for sending and receiving data to and from sensors, routing, etc.;

− Gateway logic – Controls gateway interfaces and data flow to and from sensor network. It provides an abstraction level with API that describes the existing sensors and their characteristics; provides functions for uniform access to sensors regardless of their type, location or network topology, inject queries and tasks and collect replies;

− Communication with users – Gateway communicates with users or other sensor networks over the Internet, wide area networks (GPRS, UMTS), satellite or some short-range communication technology. It is possible to build a hierarchy of gateways, i.e. to connect gateways described above to a backbone and then to provide a higher-level gateway that is used as a bridge to other networks and users.

Current Method: Existing work had the objective of minimizing the completion time of converge casts. However, none of the previous work discussed the effect of multi-channel scheduling together with the comparisons of different channel assignment techniques and the impact of routing trees and none considered the problems of aggregated and raw converge cast, which represent two extreme cases of data collection,

Proposed Method:

Fast data collection with the goal to minimize the schedule length for aggregated converge cast has been studied by us in, and also by others in, we experimentally investigated the impact of transmission power control and multiple frequency channels on the schedule length Our present work is different from the above in that we evaluate transmission power control under realistic settings and compute lower bounds on the schedule length for tree networks with algorithms to achieve these bounds. We also compare the efficiency of different channel assignment methods and interference models, and propose schemes for constructing specific routing tree topologies that enhance the data collection rate for both aggregated and raw-data converge cast.

Applications:

Here we briefly present the role played by wireless sensor network in applications ranging from environmental monitoring, industrial automation, agriculture, disaster control, automotive, structure health monitoring,

Security and surveillance:

Security and detection are the important applications of wireless sensor networks.

Sensor nodes with motion sensing capabilities may be deployed at the borders to detect the intruder crossing the line of control. Hence surveillance of regions, assets, perimeters, borders and cleared areas can be efficiently done by deploying wireless sensor networks.

Environmental monitoring

Following are some of the projects and research plans sought in the environment monitoring application of wireless sensor networks.

- Watershed: Correctly managing our watersheds is essential to ensure water supply to the increasing human population in the world. Collecting data for understanding the water systems of rivers and lakes including the impact of environmental factors and human activity.

- Scientific investigation: Sensor networks are being used for various scientific explorations including ecological and environmental ones.

- Pollution monitoring: Growing urban and industrial regions need efficient pollution monitoring technology.

- Detailed measurements of weather phenomenon at fine granularity help manage weather dependent industries such as agriculture and also help understand other effects such as spread of epidemics.

- Threat-Identification: Sensors can be used to identify potential threats such as chemical contamination of water distribution system at various locations, pathogens in the environments, and other subtle changes in critical infrastructure.

- Coal mine monitoring for poisonous gases

Creative Industries:

Wireless Sensor Networks has made a significant impact in the automation and control of the industrial processes. The benefits of WSN in industrial applications are to increase production efficiencies, to reduce environmental impact, to form a close loop by both sensing and controlling various equipments at disjoint locations. The sensor nodes can be placed at remote and manually inaccessible locations because of their small size and capability to communicate wirelessly. The WSNs are hence found useful for steel, chemical, oil and gas, pulp and paper, and petroleum industries. Further the sensor nodes capability to sense and control the atmospheric parameters makes them useful for pharmaceutical, fabrication and cultivation industries.

Precision Secures

Many initial deployments of wireless sensor networks have shown promise to address various issues faced by rural community. With the help of WSNs, many of the farming activities can be precisely done resulting in yield optimization and minimization of the cost incurred in farming. The sensor nodes may be deployed on the field to measure various atmospheric and soil parameters. These can help in making decision on irrigation, fertilizer and pesticide applications. The WSNs may also serve for the applications such as intruder detection, pest detection, plant disease prediction, fire detection, automating irrigation etc. Some of the ongoing and past agriculture projects in India are Agrisens problems that can be solved using WSNs include mush room cultivation and cattle tracking.

Disasters Response: Wireless sensor networks are also found useful for detection of various disasters such as andslide [amrita], [16], Volcanoes [17], [18] and forest fire [19]. When sensor nodes detect occurrence of any such events they communicate that information to their neighboring nodes for in-network data aggregation. A cluster head or sink node makes the decision on the disaster occurrence considering the information received from various sensor nodes. Such collaborative decision making improves the reliability of the decision made by the entire network [39-42].

Automotive Sensor Nodes:

The usage of sensor nodes in the vehicles has led to envision of various automotive applications of the wireless sensor networks. The cabling required to be done to connect various sensors in any automobile can be redundant by using wireless sensor nodes. This simplifies placement of the sensors resulting in more accurate measurements. The vehicle to vehicle communication and vehicle to roadside static node communication gives rise to enormous applications such as smart parking, collision avoidance, multimedia data transfer, disaster detection, traffic information communication. Vehicular WSN are also useful to prevent road accidents and prevent vehicles from crashing into each other, prevent speeding streamline traffic management. Some of these applications face the challenges of high speed multihop transmissions, considering high mobility of vehicles. The power constrain of a WSNs may or may not be relevant, depending on the placement of the nodes, in the automotive application.

Modules:

1. Periodic Aggregated Converge cast.
2. Transmission Power Control
3. Aggregated Data Collection
4. Raw Data Collection
5. Tree-Based Multi-Channel Protocol (TMCP)

Module Description:

1. **Periodic Aggregated Converge cast.**

Data aggregation is a commonly used technique in WSN that can eliminate redundancy and minimize the number of transmissions, thus saving energy and improving network lifetime. Aggregation can be performed in many ways, such as by suppressing duplicate messages; using data compression and packet merging techniques; or taking advantage of the correlation in the sensor readings we consider continuous monitoring applications where perfect aggregation is possible, i.e., each node is capable of aggregating all the packets received from its children as well as that generated by itself into a single packet before transmitting to its parent. The size of aggregated data transmitted by each node is constant and does not depend on the size of the raw sensor readings.

2. Transmission Power Control

We evaluate the impact of transmission power control, multiple channels, and routing trees on the scheduling performance for both aggregated and raw-data converge cast.. Although the techniques of transmission power control and multi-channel scheduling have been well studied for eliminating interference in general wireless networks, their performances for bounding the completion of data collection in WSNs have not been explored in detail in the previous studies. The fundamental novelty of our approach lies in the extensive exploration of the efficiency of transmission power control and multichannel communication on achieving fast converge cast operations in WSNs.

3. Aggregated Data Collection

We augment their scheme with a new set of rules and grow the tree hop by hop outwards from the sink. We assume that the nodes know their minimum-hop counts to sink.

4. Raw Data Collection

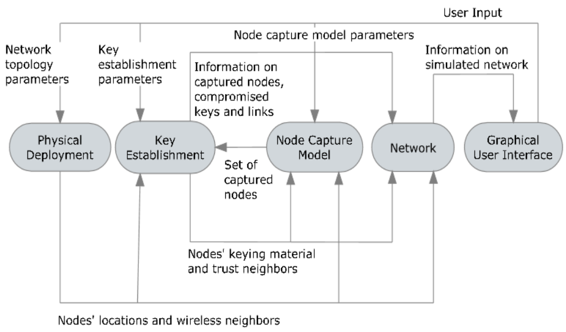
The data collection rate often no longer remains limited by interference but by the topology of the network. Thus, in the final step, we construct network topologies with specific properties that help in further enhancing the rate. Our primary conclusion is that, combining these different techniques can provide an order of magnitude improvement for aggregated converge cast, and a factor of two improvement for raw-data converge cast, compared to single-channel TDMA scheduling on minimum-hop routing trees.

5. Tree-Based Multi-Channel Protocol (TMCP)

TMCP is a greedy, tree-based, multi-channel protocol for data collection applications. It partitions the network into multiple sub trees and minimizes the intra tree interference by assigning different channels to the nodes residing on different branches starting from the top to the bottom of the tree. Figure shows the same tree given in Fig. which is scheduled according to TMCP for aggregated data collection. Here, the nodes on the leftmost branch is assigned frequency F1, second branch is assigned frequency F2 and the last branch is assigned frequency F3 and after the channel assignments, time slots are assigned to the nodes with the BFS Time Slot Assignment algorithm.

Modeling of Secure Wireless Sensor Networks:

Wireless sensor networks (WSNs) are emerging as a promising technology with a wide range of potential uses, including environmental monitoring, building surveillance, and military applications. A typical WSN consists of many (perhaps thousands) of sensor nodes deployed over a region to observe phenomena of interest. Each sensor node is a small battery powered device with sensing hardware to measure one or more physical conditions, such as temperature, humidity, pressure, sound, light, or radioactivity. Sensors have a short range wireless radio for communication, as well as limited storage (memory) and computational (CPU) resources. Sensors can be programmed to work collaboratively by collecting, exchanging, and forwarding the sensed data to WSN base stations, where data is processed and analyzed further. Two important considerations when deploying WSNs are connectivity and security. The WSN is connected if there exists a physical (wireless) communication path from any sensor node to any other node, including the base station. These paths are typically multi-hop, relying on intermediate sensor nodes to forward data. The WSN insecure if all communication paths, including the intermediate hops, are protected by pair-wise secret keys, so that all communication can be encrypted



Main components in WSN simulator

TDMA scheduling Converge cast for wireless sensor networks

Converge cast, namely collection of data from sensors towards a common sink node over a tree topology is a fundamental operation in wireless sensor networks (WSN). In many applications, it is important to deliver the data to the sink in a limited amount of time and increase the speed of data collection at which the sink can receive data from the network. For instance in Lites [2], which is a real time monitoring application, a typical event may generate up to 100 packets within a few seconds and the packets need to be transported from different network locations to a sink node. Since the data has to be delivered in a short time, we consider time division multiple access (TDMA) [3] as a natural solution due to the collision free behavior. Consider a schedule of ttime slots where the sink receives data from all nodes in the network once every t slots. In such a context, the objective is to minimize t to increase the speed of data collection. We study a set of techniques in order to solve the fundamental problem: "how fast can data be converge cast to the sink over a tree topology?" The fundamental limiting factors are interference and half-duplex nature of the transceivers on WSN nodes. To cope with interference we consider different techniques such as transmission power control and assigning different frequency channels on interfering links. We show that once multiple frequencies are employed with spatial-reuse TDMA, the converge cast schedule becomes limited by the number of nodes in the network once a suitable routing tree is used. For further improvements, we consider equipping a single sink with multiple transceivers, and also the deployment of multiple sinks to collect data. We evaluate the above mentioned techniques using mathematical analysis and simulations that use realistic channel models and radio parameters typical of WSN radio devices. The following are some of the findings and key contributions of this work

- Evaluation of transmission power control to eliminate interference: Under idealized settings (unlimited power, continuous range) power control mechanisms may provide unbounded improvements in the speed of data collection. We evaluate the behavior with an optimal power control algorithm described in [4] in a practical setting considering the limited discrete power levels available intoday's radios on WSN nodes.

- Receiver-based frequency assignment: We show that scheduling transmissions on different frequency channels is more efficient in mitigating the effects of interference compared with transmission power control. Accordingly, we define a receiver-based channel assignment problem which is "the problem of assigning a minimum number of frequencies to the receivers such that all the interference links in an arbitrary network is removed". We show that the problem is NP-complete and introduce a greedy heuristic for channel assignment. By simulations and analytical calculations, we evaluate the behavior of our heuristic algorithm and compare its performance with another channel assignment method which was recently

Preliminaries & Problem Statement: Before explaining the studied mechanisms, we first describe our preliminary design and give the details of the problem formulation. We assume time is divided into equal sized slots and each node is assigned a time slot to transmit data. All the nodes in the network except the sink are sources and generate one packet for each converge cast operation. We model the sensor network as a graph G= (V, E), where V is the set of nodes and E is the set of edges that represent communication links and interference links between nodes. A pair of nodes v i∈V and vj ∈ V form a communication link (i, j) if the signal to noise ratio (SNR) is not less than a communication threshold γ C. A pair of nodes v i∈V and vj∈V form an interference link (i, j) if the transmission from node vi disturbs a reception at the node vj or vice versa, Let s∈V be the sink node and T = (V, E T) ⊂ G be a spanning tree on the graph rooted at s. We assume G to be connected. The problem we address is the following. Given G, find an assignment of time slots to the transmitters such that the the number of time slots to complete a convergecast is minimized with subject to the following transmission constraints

- Two adjacent edges (see Fig. 1) cannot be scheduled at the same time slot. An edge (k, l) is adjacent to edge (i, j) if {i, j} T{k, l} 6 = φ.
- Two edges (i, j) and (k, l) cannot be scheduled simultaneously if (i, l) or (k, j) is an interference link.
- A node cannot be assigned a time slot to transmit a packet before it actually receives or generates that packet and a node cannot transmit more than one packet at a time slot.
- A node has a single half-duplex transceiver such that it cannot transmit and receive simultaneously and cannot receive from more than one transmitter at the same time

Description of Operation:

- **Normal packets**

The simplest type of communication that happens in a WSN is the one that we use a normal packet to execute. When a node wishes to communicate with the base station it should generate and transmit a normal packet. This means that it must create a flag that designates that this is a normal packet. Then the source, data and AM of the packet are encrypted using the normal key and a CBC-MAC which is based on them is created and appended in the very end of the packet.The packet is then transmitted in the network and any node that receives it can read the plaintext flag and understand that this packet is for the base station. Nodes that are members of the path to the base station retransmit the packet while other nodes simply discard the packet immediately after reading the flag. Upon reception of the packet the base station would validate it using the CBC-MAC as reference. If the packet was altered during transmission the CBC-MAC will help the base station detect it. If no alteration is detected the base station will change the normal key shared with the node it received information from and would acknowledge the correct reception of the packet

- **Broadcast packets**

Should the base station need to communicate with the network, for example if a command is to be sent to the whole network, a broadcast packet must be used. The base station would begin generating the broadcast packet by creating an appropriate flag. Then the AM and Data would be encrypted using the broadcast key, which is shared with the whole network. The length of the packet and the CBC-MAC would be generated and attached to the packet appropriately and the base station would send the packet. Every node will validate the packet using the CBC-MAC and then retransmit the packet for the other nodes to receive it as well. Also, every node should change its broadcast key according to the protocol.

- **Long packets**

The possibility of a note communicating with another node other than the base station is rather rare. However since some applications might require that we have also included a long

Packet format in our protocol which allows this kind of communication. Long packets take up memory space and they can be disabled if not needed by the application. They are basically normal packets but they include a destination address which can be used by the intermediate nodes to determine the route which this packet must travel in order to be received by the appropriate node. Routes have also routing keys which are used when retransmitting a long packet. The function would be similar to sending many normal packets from one node to the next and then instead of changing the pair keythe intermediate nodes should change the routing key.

Delay Rate of Data in Tree Based Wireless Sensor Networks:

In this advanced and fast world people do not want to wait much for collecting information. Hence now a day's collecting information in a faster way became a challenge for the researchers. Faster data collection in WSN with a tree based routing protocol has been discussed in this work. First of all we consider the time scheduling on a single frequency channel to minimizing the number of time slots and then we combine scheduling with transmission power control to overcome the effects of interference. This is done under a single frequency channel but with multiple frequencies it is more efficient. We also evaluate the performance of various channel assignment methods, the use of multi-frequency scheduling can sufficient to eliminate most of the interference. Then, the data collection rate increases by reducing the interference by the topology of the routing tree

Performance Evaluation

In this section, the performance of our proposed tree-based approach is compared with that of the AODV-based approach which uses AODV to set up routes for the delivery of data from RPs to the GW in the relaying network.

Analytical Results

We compare the AODV and the tree-based approaches in terms of the signaling overhead required for the route or tree branch setup from a ServingRP to the GW. For this, the following assumptions are made: Regardless of the type of control messages used in each protocol, the cost for sending one message (e.g., the message sending power) is Ct and the cost for receiving one message (e.g., the message receiving power) is Cr. There is no tree branch merging point between the ServingRP and the GW. There is no error in sending or receiving a message.

Signaling Cost of the AODV-based Approach: The route from the ServingRP to the GW is established through two steps. The first step is to flood a RREQ message from the ServingRP to the GW and the second one is to unicast a RREP message from the GW to the ServingRP.

1.Cost induced by the RREQ message. All RPs in the grid structure transmits the RREQ message only once since the RREQ message is flooded from the ServingRP to the GW. Since each RP receives the RREQ message sent by its neighboring RPs, the RREQ induced cost becomes as the following if the size of the grid structure is nRPs x mRPs:

$$C_{AODV}^{RREQ} = (n-2)(m-2)(C_t + 4C_r) + 2[(n-2) + (m-2)](C_t + 3C_r) \\ +4(C_t + 32)$$

Cost induced by the RREP Message:

With assuming that the number of hops from the ServingRP to the GW is k, each RP on the route from the erving RP to the GW receives the RREP message from its higher level RP (i.e., its neighboring RP closer to the GW) and forwards the RREP message to its neighboring RPs. The neighboring RPs at the same level of the RPs on the data route do not forward the RREP message. The refore, the RREP induced cost of the data route is

$$C_{AODV}^{RREP} = (C_t + 2C_r)k + (2k+4)C_r$$

Thus, the total signaling cost of the AODV-based approach becomes:

$$C_{AODV} = C_{AODV}^{RREQ} + C_{AODV}^{RREP}$$

Signaling Cost of the Tree-based Approach:

We assume that the number of hops from the Serving R P to the GW is k. The ServingRP sends a Construct message for the tree construction after sending out an advertisement message for the announcement of its being a ServingRP. After that, if the ServingRP receives a CONSTRUCT message from one of its neighboring RPs (i.e., this neighboring RP becomes the parent RP of the Serving RP), it sends a suppress message to prevent its other neighboring RPs from becoming a higher level RP. Thus, each of the neighboring RPs of the ServingRP which are not the parent RP of the ServingRP receives three control messages, advertisement, construct and SUPPRESS messages. Therefore, the cost at the ServingRP level is:

$$C_{TREE}^{S\_RP} = (3C_t + C_r) + 3 \cdot 3C_r$$

Except for the ServingRP, each RP on the data route from the ServingRP to the GW (i.e., a BranchRP) receives a construct message from its child RP and sends a construct message to establish a route to its higher level. After that, upon receiving a construct message from its parent RP, the Branchrp sends a suppress message to its neighboring rps to let them know that its parent rp has been determined, so each neighboring rp of a branchrp receives a construct message and a suppress message. thus, the cost incurred by branchrps is:

$$C_{TREE}^{B\_RP} = [(2C_t + C_r) + 2 \cdot 2C_r](k-1)$$

Therefore, the total signaling cost of the tree based approach becomes:

$$C_{TREE} = C_{TREE}^{S\_RP} + C_{TREE}^{B\_RP}$$

Conclusions

TDMA-based scheduling algorithms for data collection in wireless sensor networks. We classified the algorithms according to their design objectives and constraints, and provided a survey of existing algorithms with comparisons. In terms of the design objectives, most of the surveyed algorithms aim at (i) minimizing schedule length, (ii) minimizing latency, (iii) minimizing energy, and (iv) maximizing fairness, whereas some algorithms aim for joint objectives, such as maximizing capacity and minimizing energy, or minimizing delay and energy. The surveyed algorithms also vary according to the design constraints and assumptions. For instance, some of the algorithms use simple models for communication and interference while some of them assume complex transceivers available on the nodes. As it was shown in some of the surveyed papers, the unrealistic models or assumptions may heavily impact the achievable results. Use of realistic models for communication, modification of those solutions that base their assumptions on unrealistic models, implementations on real sensor nodes and performance evaluations over real testbeds and deployments, and addressing the trade-offs between conflicting design objectives are identified as some of the important directions for future research. Wireless sensor networks are an interesting research area with many possible applications. They are based on collaborative effort of many small devices capable of communicating and processing data. There are still many open issues ranging from the choice of physical and MAC layer to design of routing and application level protocols. Bluetooth is a possible choice for data communication in sensor networks. Good throughput, low-power, low-cost, standardized specification and hardware availability are Bluetooth advantages, while slow connection establishment and lack of scatternet support are some of the deficiencies. An initial implementation of a Bluetooth based sensor network platform is presented. Implemented functionality and various problems experienced during the implementation are described. Implemented platform presents a good environment for further research and development of sensor network protocols and algorithms.

References:

- K. K. Chintalapudi and L. Venkatraman, “On the design of mac protocols for low-latency hard real-time discrete control applications over 802.15.4 hardware,” in IPSN ’08, pp. 356–367.
- Talzi, A. Hasler, S. Gruber, and C. Tschudin, “Permasense: investigating permafrost with a wsn in the swiss alps,” in EmNets ’07, Cork, Ireland, pp. 8–12.
- S. Upadhyayula and S. Gupta, “Spanning tree based algorithms for low latency and energy efficient data aggregation enhanced convergecast (dac) in wireless sensor metwork” Ad Hoc Networks, vol. 5, no. 5, pp. 626–648, 2007.
- Y. Wu, J. Stankovic, T. He, and S. Lin, “Realistic and efficient multi-channel communications in wireless sensor networks,” in INFOCOM ’08, pp. 1193–1201.
- Ghosh, O. D. Incel, V. A. Kumar, and B. Krishnamachari, “Multi-channel scheduling algorithms for fast aggregated convergecast in sensor networks,” in MASS ’09, Macau, China.

- W. Song, F. Yuan, and R. LaHusen, "Time-optimum packet scheduling for many-to-one routing in wireless sensor networks," in MASS '06, pp. 81–90.
- X. Lin and S. Rasool, "A distributed joint channel-assignment, scheduling and routing algorithm for multi-channel ad-hoc wireless networks," in INFOCOM '07, pp. 1118–1126.
- Papadimitriou, "The complexity of the capacitated tree problem," Networks, vol. 8, no. 3, pp. 217–230, 1978.
- H. Dai and R. Han, "A node-centric load balancing algorithm for wireless sensor networks," in GLOBECOM '03, pp. 548–552.
- M. Z. Zamalloa and B. Krishnamachari, "An analysis of unreliability and asymmetry in low-power wireless links," ACM Trans. Sen. Netw., vol. 3, no. 2, p. 7, 2007.
- J. Gr onkvist and A. Hansson, "Comparison between graph-based and interference-based stdma scheduling," in MobiHoc '01, Long Beach, CA, USA, pp. 255–258.
- Crossbow MICAz OEM Module. http://www.xbow.com/Products/Product_pdf_files/ Wireless_pdf/MICAz_OEM_Edition_Datasheet.pdf.
- Annamalai, V., Gupta, S., Schwiebert, L.: On tree-based convergecasting in wireless sensor networks. In: WCNC '03, vol. 3, pp. 1942–1947 vol.3 (2003)
- Arisha, K., Youssef, M., Younis, M.: Energy-aware tdma-based mac for sensor networks.System-Level Power Optimization for Wireless Multimedia Communication pp. 21–40 (2002)
- Baljeet Malhotra, I.N., Nascimento, M.A.: Aggregation convergecast scheduling in wirelesssensor networks. Tech. rep., University of Alberta (2009)
- CC2420: Single-chip 2.4 ghz ieee 802.15.4 compliant and zigbee(tm) ready rf transceiver.http://www.ti.com/lit/gpn/cc2420
- Chafekar, D., Kumar, V.A., Marathe, M., Parthasarathy, S., Srinivasan, A.: Cross-layer latencyminimization in wireless networks with SINR constraints. In: MobiHoc '07, pp. 110–119.ACM, New York, NY, USA (2007)
- Chafekar, D., Kumar, V.S.A., Marathe, M.V., 0002, S.P., Srinivasan, A.: Approximation algorithms for computing capacity of wireless networks with SINR constraints. In: INFOCOM, pp. 1166–1174 (2008)
- Chatterjea, S., van Hoesel, L., Havinga, P.: Ai-lmac: an adaptive, information-centric and lightweight mac protocol for wireless sensor networks. In: Issnip '04 (2004)
- Chen, X., Hu, X., Zhu, J.: Minimum data aggregation time problem in wireless sensor networks. In: MSN, pp. 133–142 (2005)