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An Adaptive Protocol For Industrial And Control Application Using Wireless Sensor Networks

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***ABSTRACT* —** *An energy-efficient, reliable and timely data transmission is essential for wireless sensor networks (WSNs) employed in scenarios where plant information must be available for control applications. To reach a maximum efficiency, cross layer interaction is a major design paradigm to exploit the complex interaction among the layers of the protocol stack. This is challenging because latency, reliability, and energy are at odds, and resource constrained nodes support only simple algorithms.The novel protocol Breath is proposed for control applications. Breath is designed for WSNs where nodes attached to plants must transmit information via multi-hop routing to a sink. Breath ensures a desired packet delivery and delay probabilities while minimizing the energy consumption of the network. The protocol is based on randomized routing, medium access control, and duty-cycling jointly optimized for energy efficiency. The design approach relies on a constrained optimization problem, whereby the objective function is the energy consumption and the constraints are the packet reliability and delay. The challenging part is the modeling of the interactions among the layers by simple expressions of adequate accuracy, which are then used for the optimization by in-network processing. The optimal working point of the protocol is achieved by a simple algorithm, which adapts to traffic variations and channel conditions with negligible overhead. The protocol has been implemented and experimentally evaluated on a test-bed with off-the-shelf wireless sensor nodes, and it has been compared with a standard IEEE 802.15.4 solution. Analytical and experimental results show that Breath is tunable and meets reliability and delay requirements. Breath exhibits a good distribution of the working load, thus ensuring a long lifetime of the network. Therefore, Breath is a good candidate for efficient, reliable, and timely data gathering for control applications*

1, INTRODUCTION

Wireless sensor networks (WSNs) are networks of tiny sensing devices for wireless communication, monitoring, control, and actuation. Given the potential benefits offered by these networks, e.g., simple deployment, low installation cost, lack of cabling, and high mobility, they are specially appealing for control and industrial applications. The variety of application domains and theoretical challenges for WSNs has attracted research efforts for more than a decade**.** Although WSNs provide a great advantage for process, manufacturing and industry, they are not yet efficiently deployed. This is because the software for these applications is usually written by process and software engineers that are expert in process control technology, but know little of the network and sensing infrastructure that has to be deployed to support control applications. On the other side, the communication infrastructure is designed by communication engineers that know little about process control technology. Moreover, the adoption of wireless technology further complicates the design of these networks. Being able to satisfy high requirements on communication performance over unreliable communication channels is a difficult task.

Reliability: Sensor information must be sent to the sink of the network with a given probability of success, because missing these data could prevent the correct execution of control actions or decisions concerning the phenomena sensed. However, maximizing the reliability may increase substantially the network energy consumption. Hence, the network designers need to consider the tradeoff between reliability and energy consumption. Delay: Sensor information must reach the sink within some deadline. A probabilistic delay requirement must be considered instead of using average packet delay since the delay jitter can be too difficult to compensate for, especially if the delay variability is large. Retransmission of old data to maximize the reliability may increase the delay and is generally not useful for control applications.

Energy efficiency: The lack of battery replacement, which is essential for affordable WSN deployment, requires energy-efficient operations. Since high reliability and low delay may demand a significant energy consumption of the network, thus reducing the WSN lifetime, the reliability and delay must be flexible design parameters that need to be adequate for the requirements. Note that controllers can usually tolerate a certain degree of packet losses and delay. Hence, the maximization of the reliability and minimization of the delay are not the optimal design strategies for the control applications we are concerned within this paper.

Adaptation: The network operation should adapt to application requirement changes, varying wireless channel and network topology. For instance, the set of application requirements may change dynamically and the communication protocol must adapt its design parameters according to the specific requests of the control actions. To support changing requirements, it is essential to have an analytical model describing the relation between the protocol parameters and performance indicators (reliability, delay, and energy consumption).

Scalability: Since the processing resources are limited, the protocol procedures must be computationally light. These operations should be performed within the network, to avoid the burden of too much communication with a central coordinator. This is particularly important for large networks. The protocol should also be able to adapt to size variation of the network, as, for example, caused by moving obstacles, or addition of new nodes. In this paper, we offer a complete design approach that embraces all the factors mentioned above. We propose the Breath protocol, a self-adapting efficient solution for reliable and timely data transmission. Since the protocol adapts to the network variations by enlarging or shrinking next-hop distance, sleep time of the nodes, and transmit radio power, we think that it behaves like a breathing organism.

2, OUR CONTRIBUTION

The sensor information must reach the sink within some deadline. A probabilistic delay requirement must be considered instead of using average packet delay since the delay jitter can be too difficult to compensate for, especially if the delay variability is large. Retransmission of old data to maximize the reliability may increase the delay and is generally not useful for control applications. Both protocols are similar since it activates only a fraction of the nodes in a certain area at any given time. A major weakness of GAF is precisely the requirement that the routing feature be guaranteed, which results in inefficiency in terms of latency and energy consumption.

The main contribution of this system the control algorithm designers impose a set of requirements on reliability, packet delay and energy consumption that the communication infrastructure must satisfy. Breath protocol, a self-adapting efficient solution for reliable and timely data transmission. Since the protocol adapts to the network variations by enlarging or shrinking next-hop distance, sleep time of the nodes, and transmit radio power, we think that it behaves like a breathing organism. The receiver sends out beacon messages at regular intervals and a sender must wait until it receives one and respond by sending the message in the rendezvous action to minimize channel usage.

3, COMPUTATIONS OF WIRELESS SENSOR NETWORKS

3.1, Sensor Networks

we allocate the more sensors in different places, that used to collect the temperature details of the particular place, here we are using the temperature sensor to observes the temperature of the place. these sensors are collect the temperature of the several places these details are send to the cluster head.

3.2, Send sensor value

Sensors receives the temperature details after that details are send to the cluster header, in these process done by the sensor ID and cluster head system name. after that enter the values of the sensor, then these details are forward to the particular cluster header.

3.3, Receive sensor value

Here the cluster head system receive the various sensor’s temperature values from the various sensors using sensor ID and cluster header name, then cluster the given values.

3.4, Cluster Head

The cluster head used to collect the data from the sensor nodes, it collect the temperature details from the various sensors. Then the values are stored in the cluster header and arrange the values for the frequent access. Finally the values are send to the controller.

3.5, Controller

Controller gets the values from the cluster head, that values are get from the various sensor nodes. Then the controller display higher temperature values with the particular place. Controller analyze the given various temperature and find the higher temperature in which node. Then display the higher temperature in which place.

4, PROTOCOLS AND STANDARDS IN THE INDUSTRIAL WSN

As mentioned above, the application requirements for the wireless communications in the industrial environments may vary significantly. Taking the demo system presented in this Chapter as an example, the amount of data is little and the acceptable latency within tens of seconds. On the other hand, at the lowest level of the factory automation systems, also a limited amount of data is exchanged, but within very strict real-time constraints, typically 10 ms These cases provide very different requirements for the WSN protocol stack

In order to introduce radio-based technologies to the industrial automation systems, the automation domain specific requirements have to be fulfilled. These requirements include guarantees for the real-time (RT) behaviour, functional safety, and security (Neumann, 2007). However, the primary objective of the wireless sensor network design has been to maximise the lifetime of the network and nodes, leaving the other performance metrics as secondary objectives Indeed, many schemes presented in the literature do not concentrate on the joint energy conservation and real-time (RT) performance It should also be noted, that in some industrial applications, especially in the factory automation domain, the energy consumption may not be critical requirement since mains power is generally available

The protocols applied in the industrial WSN are discussed, excluding the proprietary protocols (a short introduction to several industrial communication systems as well as to some proprietary protocols can be found in Regarding to industrial WSN protocol development the following requirements can be found from the literature.

- RT, reliable communication, also in heterogeneous networks
- Coping with transient interferences: guarantee deterministic and timely data delivery in case of temporary link failures (Song et al., 2006)
- Energy-efficiency: operate at low duty cycles, maximising shutdown intervals between packet exchanges (Rowe et al., 2008))
- Deterministic node lifetime (Rowe et al., 2008)
- Scalability (Rowe et al., 2008)
- Capability for localisation, synchronization and energy management
- Safety and security (not discussed in this paper) (Neumann, 2007)

All these requirements have significant impact on the WSN protocols stack . In the horizontal planes, the layers of the Open Systems Interconnection (OSI) Reference Model protocol stack, developed by International Organization for Standardization (ISO), are presented. The vertical planes illustrate the modifications required specifically by WSN. In some applications, knowledge of positions, provided by the localisation capability, is required The power manager handles on-board power sources or energy scavenging units Finally, to support RT communication, synchronisation capability is needed.

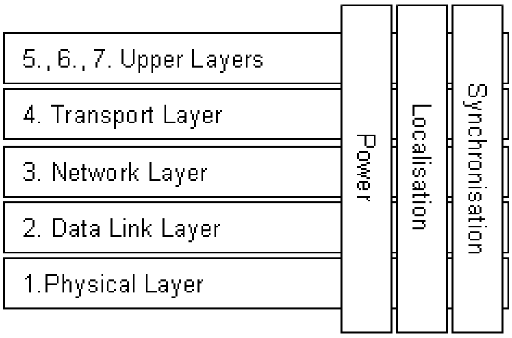

Figure: 1 They layers of the WSN protocol stack

The possible topologies include star (single-hop), mesh (multi-hop) and hybrid (cluster-tree), presented in The advantage of the star topology is energy efficiency and long lifetime, even if a node collapses. Namely, energy is not consumed on listening to network changes and relaying messages between the nodes, as in case of multi-hop architecture. As a disadvantage of the star topology, smaller number of nodes compared to the multi-hop network is allowed. However, this may not be a problem, if the coordinators use wired links. On the other hand, the multi-hop networks have a longer range and since all the nodes are identical, separate sink nodes are not necessarily needed. However, in addition to the aforementioned energy consumption, the network may suffer from increased latency. The hybrid architecture attempts to combine the low power and simplicity of the star topology as well as the longer range and self-healing of the mesh network. Also in this approach, nonetheless, the latency may still be a problem.

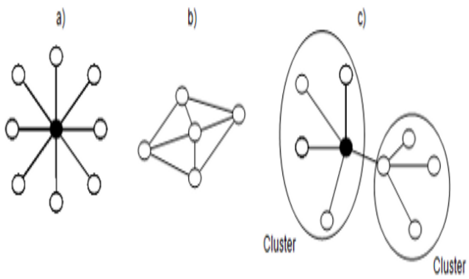

Figure: 2 WSN topologies. Star (a), mesh (b), and hybrid c)

A comparison of several different network layer protocols from network performance point of view has been presented in discusses several RT routing protocols, concerning especially the industrial applications. They also propose an approach, EARQ that takes into account the RT, reliability and energy efficiency of the communications. EARQ can set the reliability of a packet to manage the trade-off between energy and reliability. Concerning energy awareness, lost packets or packets missing deadlines, the EARQ was reported outperforms other RT protocols discussed in the study. Moreover, it was concluded, that in the practical environments networks are often heterogeneous, compromising of several technologies. Therefore, a protocol ensuring RT also in these operating environments was considered necessary.

5, ADOPTIVE APPROACH FOR TOPOLOGY MANAGEMENT LARGE AND DENSE REAL TIME WIRELESS SENSOR NETWORKS

Topology management protocols play an important role in WSNs, managing the sleep transitions of the nodes to make data transmissions occur in an energy-efficient way, thus prolonging network lifetime. However, classical topology management protocols are not suitable for real-time WSNs, as they may introduce unbounded delays. In a previous work, we presented a static topology management protocol specifically designed for real-time WSNs which is able to provide bounded delay and routing fidelity. This paper extends such work, presenting a dynamic topology management protocol that surpasses the static approach introducing support for event-driven data transmissions and node joining at runtime and providing a novel adaptive technique for energy balancing among nodes to further increase network lifetime. This paper provides a detailed description of the dynamic protocol and simulation results on network lifetime and routing performance with comparative assessments

6, AN ADOPTIVE PROTOCOL FOR HEALTH MAINTAINING AND MOBILE ROBOT

We developed an adaptive route selection algorithm for a Mobile Ad-hoc Network (MANET). This algorithm has been realized and implemented for health monitoring applications with sensor nodes and a mobile robot. The health care devices include a body-pose estimation module, and a SpO_2 and ECG sensor module. These sensor modules wore on individuals and the mobile robot itself form a mobile sensor network. Conventional Ad-hoc On-demand Distance Vector (AODV) looks for a route which has the smallest hop count, but the route with the smallest hop count might not be the best route. In this paper we propose a novel routing protocol that features to combine signal strength and battery level into account, and uses fuzzy inference to search for a route with stable RF signals. Simulation results show that the packet delivery ratio increases from 81% to 90%. In practical experiment on a Zigbee MANET, the packet delivery ratio improves from 66% to 94%. The proposed MANET has also been experimented in practical health care application by integrating a pose estimation module, a SpO_2 sensor and a mobile robot.

CONCLUSION

We designed and implemented Breath, a protocol that is based on a system-level approach to guarantee explicitly reliability and delay requirements in wireless sensor networks for control and actuation applications. The protocol considers duty-cycle, routing, MAC, and physical layers all together to maximize the network lifetime by taking into account the tradeoff between energy consumption and application requirements for control applications. We provided a complete test-bed implementation of the protocol, building a wireless sensor network with Tiny OS and Tmote sensors. An experimental campaign was conducted to test the validity of Breath in an indoor environment with both AWGN and Rayleigh fading channels. Experimental results showed that the protocol achieves the reliability and delay requirements, while minimizing the energy consumption. We are currently investigating the extension of the design methodology to consider mesh networks such as coexisting ad-hoc and wireless sensor networks.

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