Wireless Body Sensor Networks allocated Adaptive Resources using Different Schemes

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Abstract— **Wireless Body Sensor Network (WBSN) technologies are one of the main research fields in the health care and entertainment industry. These technologies aim to one day become mature enough to improve the quality of human life. For example, WBSN technologies are able to control and monitor the health status of a patient at all times, alert patients or practitioners about abnormal physical health status that otherwise would have been ignored or remained unnoticed by the patient, give enough time to the patient to seek medical care, and thus help to cure illness before symptoms become visible or the physical health of the patient becomes critical. They allow elderly and chronically ill people to maintain their independence without need for constant supervision or the presence of caregivers. WBSNs are an attractive proposal for such scenarios due to the ease of installation, their small size, low cost, low power consumption and low maintenance. Although WBSNs have significant benefits, their characteristics create numerous challenges, namely: network mobility in urban environments, interference caused by other technologies sharing the same frequency band, and most importantly, limited resources such as finite power supply, computational power, storage capacity and communication capabilities.**

***Keywords*: CAP, GTS, PAN, RSSI, Seed**.

1. INTRODUCTION

Wireless Body Sensor Networks WBSNs target applications related to monitoring and processing of human vital signs for health and well-being, entertainment and tracking applications. The ultimate goal of WBSNs is to improve the quality of human life. For example, WBSN technologies could be used to seamlessly monitor the health status of elderly and chronically ill people without the need for constant supervision or presence of caregivers, allowing them to maintain their independence and freedom.

The major difference that separates classical WSNs from WBSNs is that WBSNs usually form small to medium-sized networks, and sensor nodes are at most one to two hops away from a coordinator node. The most common topology used for such networks is the star topology with only a single-hop between the sensor node and the coordinator. Another significant property of WBSNs is their group mobility. This means that, although each node in a WBSN has limited independent internal mobility, all sensor nodes and the coordinator node move as a whole, along with the movement of their human carrier. This is also known as network or group mobility. Contrary to WBSNs, WSNs are usually static, medium to large-scale and multi-hop networks with very few mobile nodes [2].

2. BASELINE SCHEMES

Two schemes are considered as baseline schemes, namely, the non-adaptive and the genie schemes, which represent the lower and upper bound of what is achievable, respectively. The lower bound is represented by the current existing IEEE 802.15.4 standard and the upper bound is represented by a hypothetical frequency adaptive scheme capable of dynamically switching the current operating channel to the channel with the lowest interference level.

2.1 No-Adaptation Scheme

The non-adaptive IEEE 802.15.4 standard scheme itself comes in three different modes.

2.1.1 Non-adaptive CAP mode: In this mode, the sensor nodes carry out their initial associations, and any up-link or down-link traffic is handled during the CAP period of the super-frame. GTSs are not utilized or assigned.

2.1.2 Non-adaptive GTS mode: In this mode, the sensors carry out their initial associations and requests for GTS slots in the CAP period. But all other up-link or down-link transmissions are carried out in their allocated GTS slot.

2.1.3 Non-adaptive CAP+GTS mode: The sensors, similar to the previous mode, carry out their initial associations and requests for GTS slots in the CAP period. However, this mode allows sensor nodes to transmit and/or receive packets in both their allocated GTS and during the CAP period. No priority is given to either opportunity. In other words, if data packets are available and the sensor node is in the CAP period it will attempt to send its data packet as soon as possible.

In the non-adaptive scheme the coordinator does not change its channel throughout the simulation. Hence, there is no frequency adaptation. Clearly, this scheme does not require or perform any additional activities like for example channel quality measurements.

The coordinator picks its initial channel randomly at the beginning of every simulation run and never changes it. When a device becomes orphaned, it remains on the same operating channel and resumes operation when it detects the next beacon packet.

2.2 Genie Scheme

The second baseline scheme is the genie scheme. This scheme is a hypothetical scheme, enabling all WBSN nodes to measure the instantaneous RSSI levels on all channels simultaneously. The purpose of designing this hypothetical scheme is to show the potential upper bound of what is achievable if nodes in the network are given oracle knowledge of their surrounding environment like channel quality and based on this information they are able to switch their operating frequency in an ideal way (simultaneously synchronize, without any costs except energy). It is assumed that all nodes measurements are noise-free, identical and instantaneous.

In addition, before transmitting a new packet, either from the coordinator node or a sensor node, all devices in the network automatically switch to the best channel (in this scenario the best channel is the channel with the least energy the assumption that all measurements are identical lets the members unanimously agree on the next best channel), without any signaling delay or signaling costs. This scheme approximates ideal adaptation without any of the involved risks like wrong decisions resulting from measurement noise, or failure of sensors to take notice of coordinators decisions.

3. FREQUENCY ADAPTATION SCHEMES

Frequency adaptation is carried out entirely by the PAN coordinator. More precisely, the PAN coordinator performs measurements on the current channel or on other channels to judge their quality, makes the decision to change the frequency, determines the frequency to hop to, and notices the remaining nodes about the decision.

In the terminology of the IEEE 802.15.4 standard the coordinator performs RSSI measurements, as only this mode can detect the presence of other technologies. Since the MAC layer of the IEEE 802.15.4 standard does not foresee a service (or associated command frames) for channel adaptation. The IEEE 802.15.4 beacon frame can carry a variable-length payload which is utilized for frequency adaptation. The precise usage depends on the adaptation scheme, but for all schemes at least two fields are included, put together into one byte: a four-bit field indicating the next channel to switch to (next Channel), and a four-bit field (called switch Count) counting down the number of beacons to be transmitted on the current channel before switching to the channel indicated in next Channel. The second field allows to use several beacon frames to announce the new channel before switching, which in heavy interference situations can help to notify all associated devices. Further fields might be present, depending on the scheme. Another parameter used is the initial Switch Count. This variable represents the number of super-frames before the network switches its operating frequency to the next channel. In other words, when the coordinator (currently on channel co) has made a decision to switch to a new channel cn, it writes the value cn into the next Channel field of the next beacon and initializes its switch Count field with the value stored in the configuration parameter initial Switch Count. The coordinator transmits initial Switch Count beacons on channel co and then switches to channel cn. The switch Count Field is counted down while transmitting the beacons on co. After switching to cn and before any new switching decision is made, the coordinator writes cn into the next Channel field and the value 0 into the switch Count field.

4. PERIODIC SCHEMES

In the class of periodic adaptation schemes the coordinator decides about the next channel periodically, after a fixed number of super-frames, which is referred to as a hyper-frame. The hyper-frame length is fixed to ten super-frames. In other words, the operating frequency channel could be changed every ten super frames.

5. PERIODIC RANDOM SCHEME

The first periodic adaptation scheme that investigated is the periodic- random scheme. In this scheme, the PAN coordinator randomly selects a channel using a uniform distribution and independent of previous choices. There are no channel measurements involved in this scheme. The extra energy costs for channel switching, which occurs when the previous and the next channel are different, are considered in the calculation of the total energy consumption. For both practical and simulation implementation of this scheme, a pseudorandom number generator for generating a sequence of numbers that represent future channels is used. In this scheme the PAN coordinator informs the sensor nodes, during the association stage, about its current seed number, Hyper-frame size and the offset to the next Hyper-frame. Having this information, sensor nodes are able to switch channels and maintain synchronization with their coordinator even if they lose three consecutive beacon packets3. Furthermore, the coordinator updates the sensor nodes about its current seed number and offset to the next Hyper-frame by including this information in the beacon packets4.

Two variations of the periodic-random scheme, where the length of the Hyper-frame is 1 and 10, respectively. This allowed us to validate our hypothesis that reducing the Hyper-frame length the duration time spent on a given channel increases the success rate. In other words, the faster the network switches its operating channel, the smaller the chance of being affected by the possible external interference present on the operating channel this is true if the next operating channel is without interference.

6. PERIODIC MEASUREMENT SCHEME

Similar to the periodic-random scheme, the periodic-measurement scheme also changes its operating channel at the end of each Hyper-frame. However, in this scheme the WBSN coordinator takes RSSI measurements of all 16 channels during the inactive period of each super-frame, and based on the measurements taken in the last ten super-frames, at the end of the sixth super-frame of a Hyper-frame it makes a decision about the best channel for the following Hyper-frame. The decision is based on the observed RSSI values and is communicated to the sensors over the remaining four super-frames [1]. Since in this, the coordinator makes the decision, it is also solely responsible for collecting RSSI measurements from all available channels. For this, the coordinator remains active and in RX mode during the inactive period of a super-frame while all sensor nodes are in sleep mode. According to the IEEE 802.15.4 standard there should not be any activity or interference from the nodes in the same WBSN during this period. The coordinator takes eight RSSI samples from each channel during the inactive period of the super-frame. This, multiplied by the sample set size, which is equal to the number of super-frames in a hyper-frame (10), gives a total of 80 RSSI samples per channel. These RSSI measurements are assumed to be noise-free but the energy required to take these samples and to switch to all 16 channels is accounted for. If the newly selected channel is different from the current operating channel, the simulation model also calculates the cost of channel switching that the sensor incurs. After the decision is made the information about the next channel switch is then added into n subsequent beacon packets. Starting from the $(n+1)^{th}$ super-frame the coordinator and all sensor nodes that successfully received at least one of the past n beacon packets, switch to the newly assigned frequency channel. In this approach there is a possibility that a sensor node may not receive any of n beacon packets and thus is not notified of channel switching decisions. In such scenarios the coordinator and all the sensor nodes that had received one of these beacon packets would have switched to the newly assigned channel. The nodes that did not receive any of the beacon packets due to external interference would be left behind in the same channel. These nodes would become orphan nodes and forced to spend a substantial amount of time and energy on scanning all available channels in search of finding and associating to its corresponding PAN coordinator.

7. PERIODIC-MEASUREMENT-MAX SCHEME

This scheme looks for the maximum observed RSSI value out of the last ten measurement sets as a summary statistic for a given channel, and the decider chooses the channel with the smallest maximum RSSI value.

8. PERIODIC-MEASUREMENT-MEAN SCHEME

Another performance measure suggested by is to calculate the average observed RSSI value of the measurements obtained on each channel. The coordinator selects the channel with the smallest mean RSSI value (this scheme is referred to as periodic- measurement-mean scheme).

9. PERIODIC-MEASUREMENT-CARDINALITY SCHEME

This scheme selects the channel with the lowest RSSI variation. This scheme counts the number of unique RSSI measurements obtained for each channel. The channel with the lowest score is selected by the coordinator. The idea behind this choice is that channels with no or little interference are more likely to be stable in terms of energy level detected in the channel thereby having a smaller cardinality score.

10. LAZY SCHEMES

The general idea for the class of Lazy schemes is that the WBSN stays on the same channel as long as it is good enough thus the name Lazy. Channel switching happens only when the measured channel energy exceeds a pre-assigned threshold. More specifically, in the Lazy scheme the coordinator takes RSSI measurements on all channels during the inactive periods of each super-frame.

11. MAX SCHEME

Similar to the periodic measurement-MAX scheme, the coordinator collects the last ten sets of RSSI readings from each channel. In this scheme, the channel quality is represented by the maximum of those readings.

Therefore, for the Lazy schemes only the channel quality estimation of the periodic- measurement-Max scheme is used, with the exception that a channel switch is only carried out if the maximum RSSI value of the current channel exceeds a threshold of -90 dBm, and if there is another channel with a lower maximum RSSI value. This variable could be tuned according to the application and surrounding environment. Using higher values (e.g. -87 dBm) would increase the tolerance, which is suitable for environments with high noise poor. However, increasing the threshold would allow less time for the coordinator to inform the sensor nodes about the decision to switch the operating channel.

12. CONCLUSION:

Maintaining a reliable data connection between the sensor nodes and their corresponding coordinator node and to increase the overall lifetime of the network (by reducing the energy consumed by the WBSN nodes) by using adaptive resource allocation techniques in scenarios with an ever changing interference landscape.

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