Poster Abstract: Priority Message Interrupts over a Duty Cycled MAC Protocol.

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***Abstract*— Many modern radios used in Wireless Sensor Networks (WSNs) are packet based. That is, all data sent and received is in packet form. Where duty cycled communication is used a sequence of repeated small packets, which we call framelets, are broadcast for long enough to ensure an overlap with the receiver's listen time. In event driven WSNs or where there are heterogeneous sensor nodes there arises a need to support various levels of performance for various packet types since some packets may be more important than others. We propose the use of a priority interrupt mechanism that operates on the Media Access Control (MAC) layer. A node with a high priority packet to send can interrupt and seize a busy channel from lower priority traffic using a priority interrupt packet sent in the gap between two framelets. This ensures that high priority packets are sent with minimal channel access time, even in a congested channel.**

I. Introduction and Motivation

Currently wireless sensor nodes such as the MICAz or TelosB platforms incorporate packet based transceivers (e.g. Chipcon's CC2420 [1] or the Nordic nRF2401 [2]). These transceivers handle complete data packets independently from the microcontroller. Consequently, control of channel access is at a per packet level. To implement radio duty cycles with such transceivers, a sender might transmit a trail of identical packets (or framelets) of which the receiver is able to hear one in its active listening phase as in [3] and [4]. This received packet may contain the data that has to be sent or it may only be used to synchronise nodes for the actual data transmission.

A problem that arises with duty cycled transmissions when congestion occurs in the network is that some nodes may have to backoff many times before acquiring the channel. The backoff length is often related to the duty cycle period leading to significant latency increases. The problem is further compounded when multiple congested hops must be traversed resulting in unacceptable latencies.

In a WSN with event based traffic or heterogeneous sensor types a need may arise to handle various packets differently. For example a fire detection system may generate periodic keep alive messages from each sensor node as well as high priority packets when a suspected fire is detected. Likewise a WSN that does not generate event based traffic may give higher priority to routing, clustering and other control messages. A sensor node with a high priority packet requiring swift data delivery must compete for channel access with its peer nodes that may be forwarding non-vital or lesser priority traffic. A situation can therefore arise where the channel is blocked to the high priority packet by low priority traffic.

We propose a modification of the framelet scheme described in [3] to allow high priority packets to interrupt and effectively seize the channel without unnecessary delays. This is achieved by sending a high priority interrupt packet to the current sender during the gaps between framelets. Upon receipt of this message the current sender will cease its transmissions and the interrupter will immediately begin to transmit its framelet trail. By taking control of the channel during another node's framelet sequence the new sender ensures its message will be heard during the listener's next active period, dramatically reducing the latency.

This scheme can be encapsulated in the MAC layer and is independent of the routing protocol chosen for the application. It is suitable for any number of systems requiring varying types of data to be handled in different manners. The particular assignments of priority can be simply assigned by the application developer without need to know the mechanics of the underlying MAC mechanism. Note that there can be multiple levels of priority assigned and it is possible to modify the priority level of a packet in the field. Thus the proposed scheme is lightweight, generic, and extremely flexible.

II. Framelet Concept

A. Framelet Based Communication

A basic problem with radio duty cycles is the need to establish rendezvous between transmitter and receiver. Since communication can only take place when the receiver's radio is active, the transmission of frames needs to somehow overlap with this active period. Transmitter-receiver rendezvous is the overlapping of data transmission and listening activities enabling effective communication. The following describes an implementation of rendezvous in duty-cycled systems for packet based radios.

B. Assumptions and Definitions

It is assumed that the clock of transmitter/receiver operates at approximately the same rate. Note that this only means negligible clock drift between nodes over a short period, not synchronised time or sleep cycles. Use of a fixed rate radio duty cycle is also assumed, i.e., each node periodically activates its radio for a fixed time interval to monitor activity in the channel. The duty cycle period is represented as $P = \Delta + \Delta_0$, where Δ is the time the radio remains active and Δ_0 is the time the radio is in sleeping mode. The duty cycle ratio,

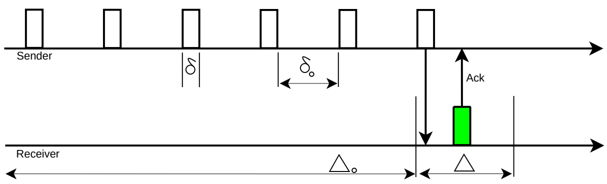

Fig. 1. Framelet-rendezvous

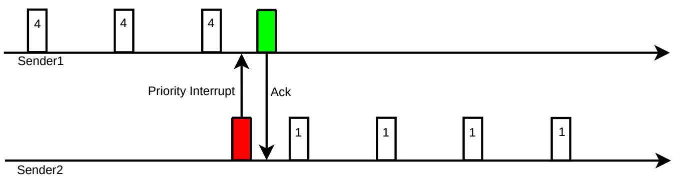

Fig. 2. High Priority Interrupts

or duty cycle for short, is defined as:

$$Duty\ Cycle = \frac{\Delta}{P} = \frac{\Delta}{\Delta + \Delta_0} \quad (1)$$

C. Rendezvous using Framelets

Framelets are defined as having a fixed or limited size. Rendezvous requires the repeated transmission of several frames containing the entire payload as depicted in Fig. 1. If the receiver captures one framelet, the payload is received. The trail of framelets is defined by three parameters:

- Number of transmissions n
- Time between framelets: δ_0
- Framelet transmission time: δ

To ensure rendezvous, a proper relationship between Δ, Δ_0, n, δ, and δ_0 must be obeyed. First, the listening phase of duty cycle Δ must be such that $\Delta \geq 2 \cdot \delta + \delta_0$, ensuring that at least one full framelet will be heard during a listen phase. Furthermore, to ensure overlap between transmission and listening activities, the number of retransmissions n must comply with the following inequality when $\Delta_0 > 0$

$$n \geq \left\lceil \frac{\Delta_0 + 2 \cdot \delta + \delta_0}{\delta + \delta_0} \right\rceil \quad (2)$$

This guarantees the framelet trail is long enough for rendezvous with the listening phase of the receiver and that at least one framelet can be correctly received.

In general, the values of δ and δ_0 should be minimised, as this influences according to equation 1 the shortest possible duty cycle active time Δ. The length of time Δ determines the message delay, throughput and energy saving.

D. Acknowledgments

Framelets can be individually acknowledged by the receiver as shown in Fig. 1. This technique allows the transmitter to stop resending framelets shortly after rendezvous is established. If acknowledgments are not used no less than the number of frames specified in inequality 2 must be sent.

III. Interrupts

Prior to sending any message a node (Sender2 in Fig. 2) must sample the channel for a given period to ascertain whether or not it is free. This period must be long enough to allow for a framelet and the space following, i.e. the length of the duty cycle active period. During this "presend" listen a node will overhear a framelet from any currently sending node. Sender2 can then compare the priority of its message with that of the message overheard from Sender1. If it finds its own message is of higher priority the gap between framelets is used to send an interrupt to Sender1 requesting the channel, otherwise it backs off and tries again later. On receipt of a high priority interrupt packet a node relinquishes the channel and backs off, restarting its framelet trail later.

IV. Application Areas

The following scenarios are among those that can benefit from the use of this scheme.

A. High Priority Event Detection

The mechanism can be used in event detection allowing high priority messages to be delivered without delay. Consider a WSN consisting of duty cycled nodes equipped with vital signs sensors attached to several patients in a hospital. If one of the nodes detects a patient is in a distressed or critical condition it is essential that a health-care worker is notified immediately. By assigning the highest priority to its message the node can interrupt any other node that is currently using the channel, thereby minimising latency.

B. Heterogeneous Sensor Networks

Heterogeneous Wireless Sensor Networks can have many nodes equipped with a variety of sensors. The data from some may be more important than others. This scheme allows each sensor to be assigned an individual priority allowing more important information to be delivered in a more timely manner.

C. Fairness

In a congested network a node may find a constantly busy channel leading to multiple backoffs and long delivery delays. A node may suffer multiple backoffs and therefore receive an unequal share of the available bandwidth. Dynamically increasing the priority of a message with each successive back off allows a node to interrupt any lesser priority message ensuring no node is frozen out for long periods.

V. Acknowledgment

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References

[1] Chipcon CC2420, http://www.ti.com/lit/gpn/cc2420
[2] Nordic, http://www.nordicsemi.com/
[3] A Barroso, U Roedig & C J Sreenan. Use of Framelets for Efficient Transmitter-Receiver Rendezvous in Wireless Sensor Networks. In 5th Int IEEE Workshop on Wireless Local Networks (WLN2005), Nov 2005.
[4] TinyOS 2.0.2, http://www.tinyos.net/