Simple spontaneous mechanism for flexible data communication in wireless ad hoc sensor networks

Antonio E. Gonzalez-Velazquez, Lionel Sacks
University College London
Electronic and Electric Engineering

Ian W. Marshall
BTexact Technologies

Abstract

A novel communication model, for lightweight ad-hoc wireless communication between highly mobile sensors is proposed. The model makes extensive use of gossip-like mechanisms, which extend the ad-hoc capabilities from the network layer into the application layer, thereby minimising application layer overheads associated with state, and incomplete sessions. We introduce a particular implementation for the proposal and initial results are drafted.

1. Introduction

Prominent research in ad hoc sensor networking has been taking place inside diverse research groups. A leading example – the Berkeley SmartDust project [1] - has proposed a lightweight model for wireless network communication between resource starved smart sensor nodes, and provided convincing initial demonstrations. However, the Berkeley proposals, in common with many others, only consider the network to be ad-hoc. The application is assumed to be a sequential source and sink for network level events. We believe that the full benefit of ad-hoc networking can only be realised if the application is also engineered to be as ad-hoc as possible. This means that one must avoid any assumptions of consistency and completeness that lead to large requirements for state maintenance in the application layer. In other words the links between collaborating nodes that collectively form the distributed application must be informal and non-deterministic wherever possible. This requirement can be generalised as ad-hoc communication, where communication implies transfer of semantic understanding. An appropriate analogy is with informal human networks, where information is circulated through ad-hoc exchange of gossip when individuals meet. We therefore propose an ad-hoc communication model based on gossip-like mechanisms.

In earlier work [6], we demonstrated the importance of having a reliable platform for experimentation and fast prototyping of ad hoc wireless sensor networking in addition to suitable simulation models. In our case the Lego RCX was used as an experimental node. The H8/3292 micro-controller along with serial communication interconnected to infrared circuitry, provides native 50% and 75% duty cycle for internal infrared diodes running with a 38KHz carrier; this arrangement provides 2400 bps raw signalling that could be speed up to 76KHz carrier for up to 4800 bps.

Vahdat and Becker [4] have also proposed a mechanism for ad hoc communication using Gossip techniques and some of the conclusions suggest that the probability parameter used for message dispersion can be modified to achieve different performance goals; although their work has not taken mobility impact into consideration. Vahdat and Becker's proposal is aimed at networks with connectivity scarcity, and they have demonstrated high utilisation through measurements of buffer usage. However, their proposal cannot take advantage of multiple participants for data exchange and depends heavily on a pre-assumed session time length. This leads to difficulties in mobile scenarios where the lifetime of a connection is transient and likely to be shorter than the session length. For gossip-based routing Li et.al [5], expose how a simple internal event, like tossing a coin with specific probability, could be used for controlled spreading of data through the network, and have proposed the use of hash functions to describe the contents of the local queue to be exchanged later in anti-entropy sessions that lead to message interchange. This also implies a heavier requirement for state maintenance than our proposal.

In this paper we aim to establish how the unexpected casual contact between nodes suits faster methods for message exchange; and how simple methods for quick and undemanding reaction to message interchange can be appropriate for local resources and variable network conditions. Initial results with experiments using the RCX as wireless sensor node for this communication arrangement are introduced and future actions are presented.

2. Infrared communication for the RCX

The RCX infrared components are pre-configured for 2400 bps communication. It uses the 38 KHz carrier for sender-receiver synchronization as well as for reducing the load cycle on the LEDs that drive the circuit. In its default configuration, RCX adds bit balancing a technique for reducing errors due to environmental light interference. This technique adds the bit complement equivalent byte for every byte to be transmitted, plus the preamble and ending for being 8 N 1 compliant; coding a zero as 417 microseconds of the 38KHZ carrier and a one as 417 microseconds of nothing. This arrangement could actually transmit 22 bits for every byte received for transmission.

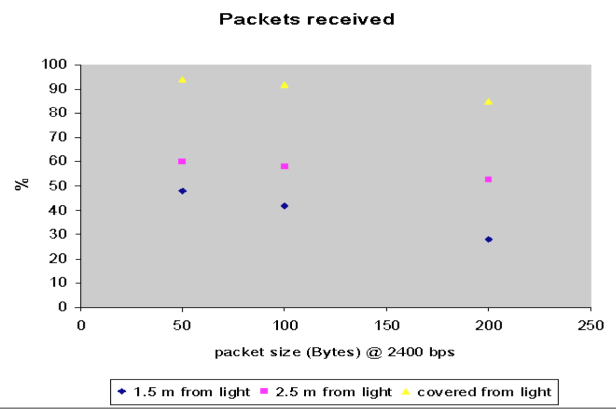

Figure 2. Percentage of packets received in light conditions

Having the experiment setup with three nodes chained to data exchange, we sent continuous data messages with fixed length, and we repeated the experiment under the halogen type lights available in the laboratory from 1.5 and 2.5 metres away from the light source, and one using a large shade to avoid direct light contact with the receivers. The results are shown in Figure 2. From the results we see that the components in the RCX are vastly affected by strong light conditions, and packet deterioration can be seen for longer packets. For the last condition, we can assume longer exposition to light noise and poor error (unique parity bit) recognition as the causes. Further analysis in the search for optimal packet size under different conditions is needed.

3.1. Time available for data exchange

Given conditions of rapid mobility, only a limited period for data communication could be expected from at least two nodes with autonomous trajectories. From experimental observation one second represents a good approximation for a one-second period using 2400 bps and the regular coding scheme available 100 bytes can potentially be transmitted. Extra computation based on selection of data to be transmitted and careful parsing of messages could waste valuable time. Simple and prompt reaction to messages received and opportunistic sending is required. The nodes should also support the exchange of data without requiring establishment of a session.

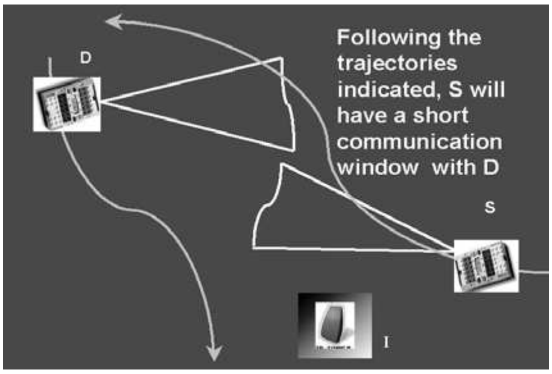

Figure 3. Opportunity in data exchange

Once two nodes are aware of each other's presence as Figure 3 shows, they should be able to exchange data in a very spontaneous way. Previous exchanges could be remembered to avoid redundant exchanges, but this is not necessary. A single node can successfully carry messages across the network with minimal assumptions, and should be able to adapt to different conditions of density and total connectivity and still aim for a variable percentage of packet delivery and expected latency with the resilience we could expect from an ad hoc network.

4. Proposal description

Following our proposal, nodes do not need to be aware of a specific state to successfully exchange data. In a highly mobile environment where contact with others is intermittent, each node attempts to propagate their local data pool based on a gossiping mechanism. The local data pool is referenced by fields like end destination, last recipient and last propagation time. The gossiping mechanism decides what piece of data should be the next one to be promoted on the basis of least recently promoted data not sent to current contact. This mechanism avoids complex selection criteria (and associated overheads), but it’s able to take advantage of identifying neighbours in its vicinity.

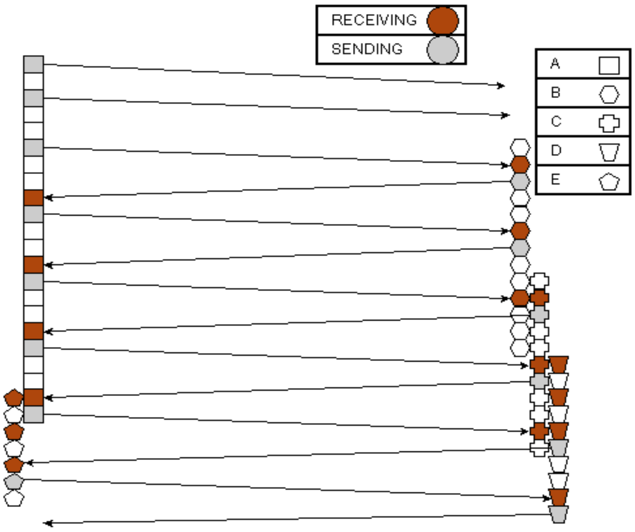

Figure 4 Ad hoc communication

Figure 4 illustrates the sessionless ad hoc interaction amongst mobile nodes. Node A is broadcasting useful messages (data record + id) at pre-selected intervals. When B meets A; B will respond by promoting a record to A, A will then send a new record to B. The conversation continues till no response is received because B is out of range. Other nodes (C,D) can join the conversation at any time, providing they are within range, by sending packets to A and B. Conflicts are minimised by giving each node a random response time interval (i.e. there are small gaps that can be exploited by nodes entering the conversation), and also by disabling the transmitter when there is a signal at the receiver

For achieving the networking facilities we have developed the following modules:

Message pool – All messages are asynchronously handled to an indexed memory space.

The Record – Keeps information about communication history; accessible fields like last transmission time and last message promoted form part of this space. Its contents are kept fresh considering former successes and time received.

Exchange – Mechanism for fast message reception and selection of the message suitable to be promoted next. It implements the gossiping mechanism.

Extensions to applications – Represent the functions and libraries the applications access for asking data to be delivered to the data collector. It sustains control signals with the Exchange.

Low level drivers for adapting the infrared interface to our objectives were also developed. Figure 5 shows the general design.

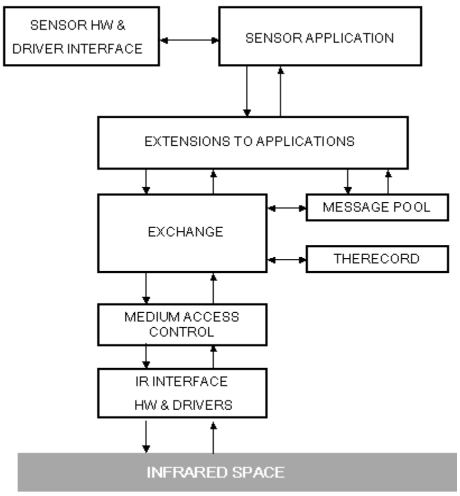

Figure 5. Diagram of the communication mechanism

4.1 Undergoing experiment and initial results

Figure 6. Initial experiment

We have set up one initial scenario for experimentation: In a self-enclosed office in Ross Building, we have set up two completely built robotic construction nodes and one in a fixed position, in one corner one Data collector (IR tower) is ready to receive messages from nodes. The nodes should be able to move freely across the carpet and the space avoiding obstacles, including other nodes; some area is sheltered from artificial light. The experiment is being tuned to run for slightly different scenarios; analysis of message and time delivery should follow. Figure 6 illustrates this scenario.

4.1.1 Initial results

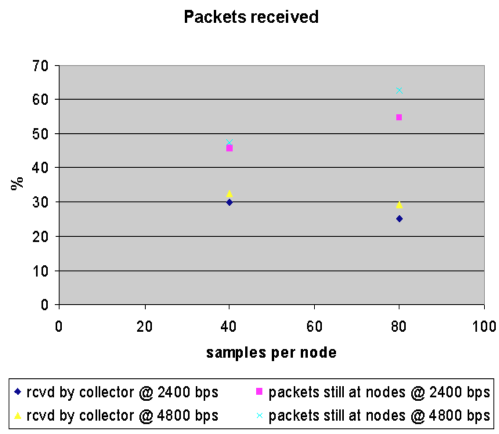

Figure 7. Data collection

The initial experiment ran for 30 minutes and developed 40 and 80 samples per node, 3 samples per minute, using 2400 bps and 4800 bps with default configuration. The Exchange was implemented using First arrived - first to be promoted priority. The Figure 7 shows the results. Despite of the increase of the speed to 4800 bps, the performance did not increase at the same rate; we have found that at 4800 bps the receivers find it difficult to synchronize themselves with the transmission, and are more sensitive to changes of position, despite that they can exchange more messages in the same window time. There is a considerable number of packets still alive in the nodes that have not arrived at the collector, we could expect that with the actual informal mobility conditions and more time for the experiment to run will bring more packets to destination, although not necessarily all of them will arrive at the data collector using the actual scheme in the Exchange

Future improvements in the exchange could bring higher delivery rate. Given the reduced amount of nodes and sampling messages, the space available in the structures Message pool and The Record is not relevant; we could expect that the coordination amongst of the Exchange mechanism and the designated space could partially overcome the potential saturation of the total network's capacity for carrying messages without time bounds.

Conclusions and further work

It is clear that mobile ad-hoc systems have communications requirements that are very different to those that are normally expected in conventional applications. We have introduced a novel spontaneous and flexible communication technique suitable for highly mobile wireless ad hoc sensor networks; together with some initial results. Although the work is clearly in its early stages, we believe the early results are encouraging. We intend to continue with more complete implementation and experimentation, alongside a simulation that should demonstrate our proposals scale. Ultimately it is crucial that the designs are tested in a realistic application context, to demonstrate that our proposals are fit for purpose. We therefore plan to field trial our system in a real sensing application, in an estuarine environment.

References

[1] Hill, J., Szewczyk, R., Woo, A., Hollar, S., Culler, D., and Pister, K., "System architecture directions for networked sensors," *Acm Sigplan Notices*, vol. 35, no. 11, pp. 93-104, 2000.

[2] H.Lundgren and D.Lundgren and J.Nielsen and E.Nordström. A Large-scale Testbed for Reproducible Ad hoc Protocol Evaluations. unpublished. 2002.

[3] A.LaMarca and W.Brunnete and D.Koizumi and M.Lease. Making sensor network practical with robots. to be published 2002 International Conference on Pervasive Computing. 2002.

[4] A.Vahdat and D.Becker. Epidemic Routing for Partially Connected Ad Hoc Networks. 2000. Technical Report CS-200006, Duke University, April 2000.

[5] L.Li and J.Halpern and Z.Haas. Gossip-based Ad Hoc Routing. unpublished . 2002.

[6] A.E.Gonzalez-Velazquez and L.Sacks and I.W.Marshall. Ad hoc sensor network experimentation using the RCX by Mindstorms. to be published IFIP WG6.7 Workshop Eunice 2002. 2002.