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# Is Multicast useful in Health Care Monitoring Systems?

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**Abstract**—Health care monitoring is a technique for early detection of many symptoms and illness. As a step forward to ubiquitous monitoring, wireless sensor networks could be a solution for health care monitoring. However, wireless sensor networks do not support heavy load because they have limited energy, short transmission range, low throughput and small memory storage. This paper uses multicast protocols to reduce the network load. We tested some multicast and unicast routing protocols under a mixed mobility model for health care using the NS-2 simulator in wireless sensor networks. Our simulation results show that the On-Demand Multicast Routing Protocol (ODMR) performs better than other routing protocols in terms of Packet Delivery Ratio (PDR) and Normalized routing overhead.

## I. INTRODUCTION

Preventive and palliative medicine can use health monitoring as an efficient technique for early detection of many symptoms and illness, and therefore saving lives. A system allowing to periodically gather health status information is very interesting and important. It can offer more regular status information about a specific feature (e.g. Cardiac dysrhythmia) than a single visit to a doctor. With a health care monitoring system it is possible to follow patient's health status permanently. However, it is not easy to follow patients, because they are usually moving in many locations (e.g. hospital, home, transport). In this context, tiny wireless sensors could be one of monitoring solutions to measure and transfer patient's health status in real-time. Wireless sensors networks are often based on the IEEE 802.15.4 standard, see [1].

The process that represents our health care monitoring system could include the following steps: 1) Capture of physiological parameters (e.g. blood pressure) using wireless sensors; 2) Communication of sensed data to monitoring subscribers; 3) Analysis of received data and 4) Some preventive actions if needed. This work focus on the second step, which involves transmission of sensed data to all persons interested in a specific patient. Data collected can be processed locally or send through Internet for further processing. Figure 1 shows an example of topology; crosses represent subscribers and patients are publishers of their own sensors data. This is a “publish and subscribe” approach because many subscribers watch the same patient's data, at least a nurse or a doctor permanently. It is a content-based system like any news dissemination application. In this system news (data) are generated by sensors and distributed to doctors and

nurses. This suggests that the network layer should support multicast semantics as stated in [2]. Although, it is interesting to compare unicast and multicast routing protocols in this application.



Fig. 1. Hospital with patients wearing sensors and doctors monitoring them.

However, there are many challenges because Wireless Sensor Networks have limited energy, short transmission range, low-bandwidth and small memory storage. Thus, these networks cannot support heavy load in comparison to an IEEE 802.11 network. Because of their low throughput, the load of health care monitoring system can be a major problem. In general, a node in the network is called mote and can play several roles. A “source” node samples its sensors and send data by radio (see Intel Digital Health Group’s **Sensing Health with Intelligence, Modularity, Mobility, and Experimental Re-usability**[3]). The “destination” node is called sink.

Motes have been used in many other applications. Usually the type of transmission is multi-point to point (one sink) for data gathering applications. Ingelrest et al. studied the energy consumption and PDR in sensor networks without mobility of stations and only one sink in [4]. Their paper gives a general idea of the problems that arise while doing a real implementation. For example: Clock drifts due to temperature changes, hardware failures (short circuits), debugging devices once deployed, radio interferences, and outliers values from sensors. In [5], Lorincz implemented a platform for motion analysis. They show that raw data from gyroscopes and accelerometers

had to be transmitted in a one-hop architecture because a multi-hop topology is not an option due to the amount of data generated. A multicast network protocol for static nodes with multiple sinks was used by Feng and Heinzelman in [6]. However mobility is not present in this geographic aware protocol. Usually this kind of protocols assume that a node knows somehow its position.

Another multicast protocol, **Adaptive Demand-driven Multicast Routing** protocol [7], has been implemented into a smaller platform (e.g. TinyOS-1.1). But not all protocol's functionalities were implemented by Chen et al.[8]. Nevertheless some improvements were proposed to obtain a more suitable routing metric in low range scenarios. They tried to find a better metric for the routing protocol using Link Quality Indicator (LQI) and hop count. Devices used in that study did not have enough storage memory, making it difficult to keep routing information. This implementation was later used in [2]. However, the majority of their 30 nodes were static which is different from the topology used in this work. Another solution to capture health status information is to use SHIMMER platform which can handle micro SD cards, so sensors can store more information including routing tables.

In wireless local networks (IEEE 802.11), multicast protocols like: On-Demand Multicast Routing Protocol (ODMR)[9], ADMR[7], and Protocol for Unified Multicasting through Announcements (PUMA)[10] were developed. In this context, simulations consider radio range up to 250 meters and a nominal bandwidth value of 2 *Mbps*. They deal with high mobility scenarios, from 1 to 20 *m/s* with a Random Way Point model. Statistics about this mobility scenario reveal that there are no isolated groups of nodes which can not communicate with each other, and path availability is 100%. However, IEEE 802.11 technology needs more power and larger materials.

The organization of this paper is as follows: Description of protocols used is found in section II. In section III we describe simulations set-up and configurations. Then in section IV we show and analyze our conclusions.

## II. MULTICAST AND UNICAST NETWORK PROTOCOLS STUDIED

Multicast protocols designed for **Mobile ad hoc networks** (MANET) have a good performance under low-speed mobility. In this work they are tested under low-bandwidth conditions due to MAC layer used. ODMR[9], ADMR[7], and PUMA[10] are routing protocols not relying on another unicast protocol to operate.

The main reason to choose multicast protocols is because we think less packets will be sent and more receivers (sinks) served. Our target scenario has an original mix of two mobility patterns for pedestrians. Patients move according to the Reference Point Group Mobility Model (RPGM), which is presented in [11], [12]. In this case, each patient represents a group of sensors; those nodes share patient's body and for this reason they move together. Nurses and doctors use a Random Walk mobility model. Both models choose a random destination

point and a speed between [*MinSpeed*, *MaxSpeed*]. At the destination, nodes choose a pause time between [*Min Pause-time*, *Max Pause-time*]. The only difference between the two mobility models is that in RPGM a group of nodes choose the same direction instead of using an independent one for each node.

Below there is a brief description of protocols studied:

**AODV** establishes routes on demand by using 2 types of control packets (*Route-Request* and *Route-Response*) to define a distribution tree. As a unicast protocol, it stores routes according to the destination address. Hello messages are used to collect topology information. If there are not data packets to send, no control packets are sent.

**ODMR** periodically floods *Join-Query* packets by each source in a multicast group. In this way it forms a forwarding set of nodes or "forwarding group" for each multicast group. It maintains and use multiple redundant paths, because other nodes store information about sources and groups forming a mesh. A receiver joins a group by sending a *Join-Reply* packet. When a node receives a *Join-Reply* packet, it determines its participation in the forwarding group. Only source nodes can generate *Join-Query* packets, and only when there is data to transfer; otherwise it just stops generating this kind of packets and the route expires. This can be implemented with a timer, if no data packet was generated by the end of the timer the protocol stops flooding *Join-Query* packets.

**ADMR** was designed for small data packets and mobile nodes to adapt to topology changes with low overhead. It maintains source-based trees, i.e., a multicast tree for each source of a multicast group. Control information is added into data packets as options. When a Receiver or subscriber wants to collect data from a group it forwards a *MulticastSolicitation* packet to all its neighbors. When a Source starts generating information it forwards a *SourceInformation* packet. Once a receiver obtains a *SourceInformation* packet, it replies with a *ReceiverJoin* packet to the source node. The source node sets up a timer to know how much time it has to wait until reset its routing state if no *Join-Request* arrives. If there is no data to send, the source node broadcasts *Keepalive* and *SourceInformation* packets for a fixed number of times before it silently stop sending those messages. Source information packets are used as ACKs at routing level (piggybacking). Forwarding state is specific to each sender rather than being shared for the entire group.

**PUMA** follows a receiver-initiated approach. It determines and uses a core node to initiate the mesh structure. It establishes and maintains a shared mesh for each multicast group. the core utilization can reduce routing overhead, because only the core node can flood the network. This protocol uses very light signaling packets called **Multicast Announcements (MA)** to do all tasks in routing. PUMA can achieve high data delivery ratio with very limited control overhead. Receivers keep sending MA until a source for that group is found. When a node has data to send, it broadcasts **Multicast Announcements (MA)** periodically.

### III. SIMULATION ANALYSIS

The main idea is to test unicast and multicast routing protocols, considering topology changes due to mobility pattern and with multiple mobile sinks. Table I summarizes scenario characteristics.

TABLE I  
PARAMETERS USED IN SIMULATION.

Parameter	WSN	Scenario statistics	WSN
duration	2 000 s	tx range	15 m
area	$50 \times 10 \text{ m}^2$	avg. degree	19.6 nodes
nodes	35	partitions	1.07
receivers	5	link breaks	3517
nodes per group	5	avg. link duration	170.3 s
Min, Max speed	(0.2, 1] m/s	total links	4032
pause time	(0, 300] s	average path availability	98.4 %

Scenarii are randomly generated and analyzed using the BonnMotion [13] mobility generator. BonnMotion offers some statistical data for each scenario. Statistics presented in table I show the average scenario values for a transmission range of 15 m.

The average connectivity degree represents the number of neighbors a single node can reach within its transmission range during simulation. The average number of partitions shows how many segments are present during run time. 1 means a single segment; that is, the network is always connected, while a larger value may express that isolated portions of network exist. The next three values show the number of links, number of broken links, and average duration of a link. It is possible to interpret broken links as an opportunity for routing protocols to adapt to topology changes. Average path availability metric takes two random nodes and calculates if a route exist between those two nodes. It is important to say that these values are independent of network protocols and configurations. Because values are calculated only using transmission range, and they should be taken as references from a topological point of view. Figure 2 shows a screen-shot of a topology with 6 groups; each group has 5 sensor nodes; nodes numbered from 30 to 34 represent sinks (nurses and doctors).

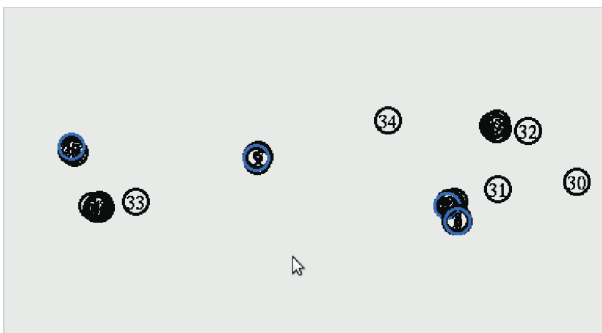


Fig. 2. Topology screen-shot, Node IDs superior to 29 are sinks and the others are organized by groups of five sensors.

In our scenarios, nodes moving in group act as sources, using a Constant Bit Rate (CBR) traffic pattern. CBR generates

1 data packet (24 bytes) each 5 and 10 seconds for the first and the second scenario respectively. With this data generation rate all routes hold by routing protocols will expire before the next data packet generation. For this reason, parameters for route expiration have been modified. PUMA's MULTICAST ANNOUNCEMENT changed from 3 to 60 seconds; ODMR's Join Query refresh interval varied from 2 to 60 seconds, while ADMR's default Inter Packet Time went from 200 ms to 30 seconds. This implies that a Source Information packet will be send every 60 seconds. AODV's routes were originally valid for 10 seconds, but timers were modified to be valid for 60 seconds. To compare multicast and unicast routing protocols, destination nodes in unicast scenarios receive the same number of data packets than in a multicast cases. One source and two receivers (a nurse and a doctor) scenario in multicast cases is represented as two independent flows in Unicast, which indeed generates more CBR packets. The simulator used in our study is NS-2 version 2.34 [14]. We made some changes in the simulator to integrate some routing protocols for multicast (ODMR, ADMR and PUMA) from version ns-2.1b8.

The metrics used in evaluation are:

- **Packet Delivery Ratio (PDR)** is the ratio between the number of packets originated at the Application layer and the number of packets received at the destination. In multicast we consider subscription's time of each sink in order to correctly measure this metric, because all sinks start receiving data packets at a random time.
- **Number of Data and Control Packets Transmitted per Data Packet Delivered**, or Normalized packet overhead is the total number of all data and control packets transmitted by each node in the network (either originated or forwarded), divided by the total number of all data packets delivered.
- Ratio between MAC collisions and MAC transmitted packets, gives an idea of collisions in the network.

#### Simulation results

*Varying number of sources:* This scenario changes the number of sources per group with three sinks per group. Figures 3 and 4 show results for three receivers while changing the number of sources per group. In this case PDR decreases as the number of sources per group grows. This is because load of the network is growing. Performance of AODV degrades faster than multicast protocols. This is due to the number of connections needed to serve all subscribers, as showed in figure 5; AODV produces more overhead than multicast protocols. We had some problems with AODV's implementation. As a source can have 5 CBR data generators running at the same time it can raise a problem in the state machine while a route is being repaired. In the context of multicast protocols, ODMR generates more overhead than ADMR and PUMA. In spite of a superior number of sources per group, PUMA continues to decrease its normalized overhead; whereas ODMR and ADMR remain stable in terms of normalized overhead. PUMA can send many Multicast Announcements from different groups in a packet, while other protocols generate control packets by

group or by source. This way, there are less control packets in the network.

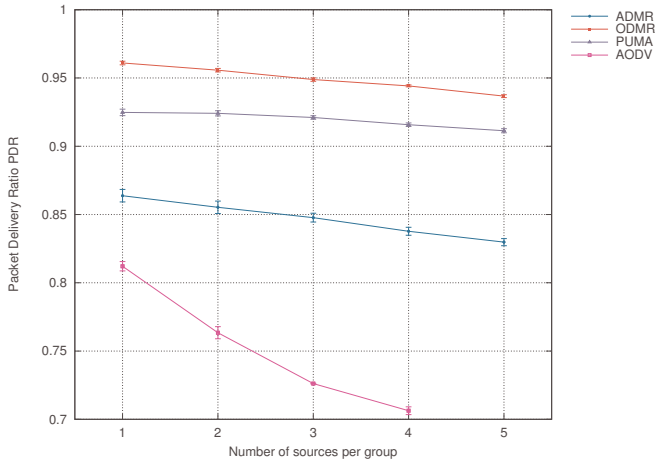


Fig. 3. PDR for scenarios with 1 packet generated every 10 seconds, 6 active groups with 3 receivers per group with original timers.

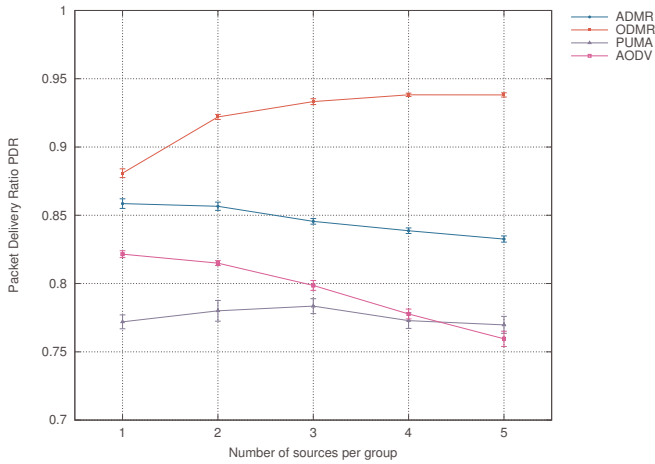


Fig. 4. PDR for with 1 packet generated every 10 seconds, 6 active groups with 3 receivers per group with new timers .

Figures 8 and 7 show the ratio between collisions and received packets during the simulation, all nodes included. With the new timers collision grows with the number of sources.

#### IV. CONCLUSION

In this paper unicast and multicast routing protocols have been compared for a possible application in health care systems. According to our results, multicast protocols perform well not only in IEEE 802.11 networks but also in IEEE 802.15.4 ones. We observe that simple mechanisms for route establishing, as those used by PUMA, seem to work better using less control overhead and dropping less packets. Other protocols like ODMR generate more routing overhead but obtain a higher PDR. However, this work shows that it is

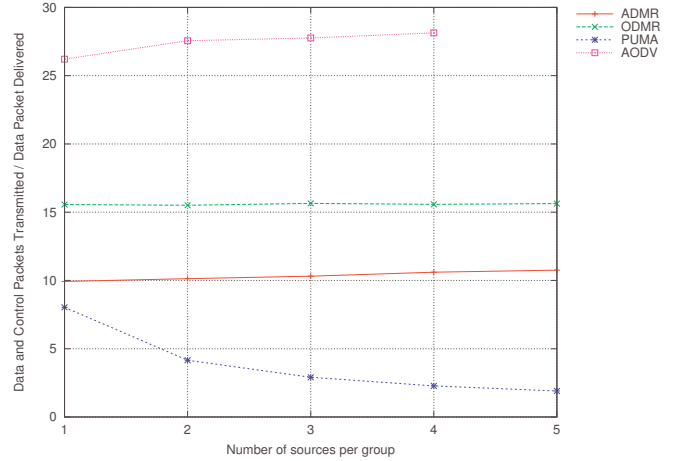


Fig. 5. Data and Control Packets Transmitted per Data Packet Delivered, 1 packet generated every 10 seconds, 6 active groups with 3 receivers per group with original timers.

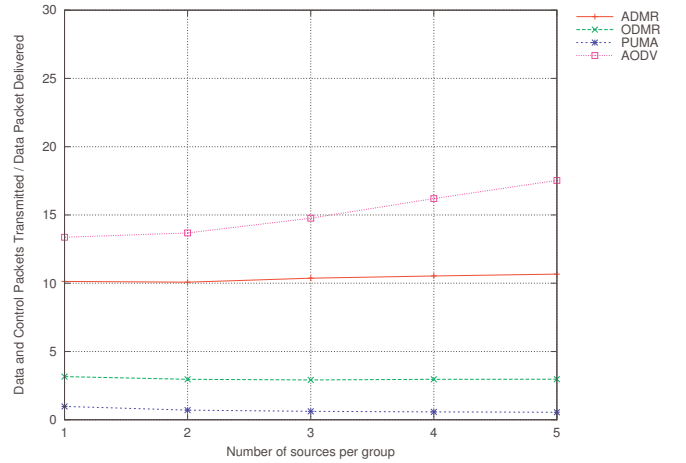


Fig. 6. Data and Control Packets Transmitted per Data Packet Delivered, 1 packet generated every 10 seconds, 6 active groups with 3 receivers per group with new timers.

possible to Improve Multicast routing protocols by adapting their timers according to this low-speed and low data rate scenario. Specifically, ODMR has better PDR than other protocols and by changing timers total overhead has reduced too. In function of features of WSN using IEEE 802.15.4, we think ODMR protocol is a trade-off solution.

As future works we can enumerate:

- In order to deal with collisions at the medium access layer, test a Beacon enabled Peer to Peer topology with different Beacon Order (BO) and Superframe Order (SO).
- Organizing sensors in clusters, reducing transmission range of simple sensors with only one node in a group participating in routing. It implies adapting routing protocols to work under asymmetric links and using a star topology.

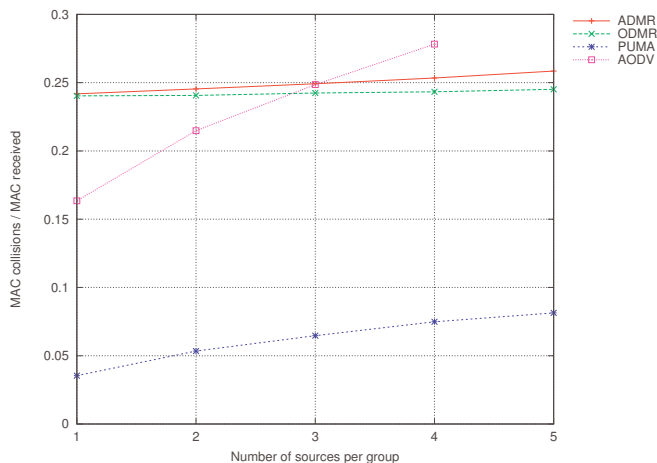


Fig. 7. Collisions / received packets ratio. 1 packet generated every 10 seconds, 6 active groups with 3 receivers per group with original timers.

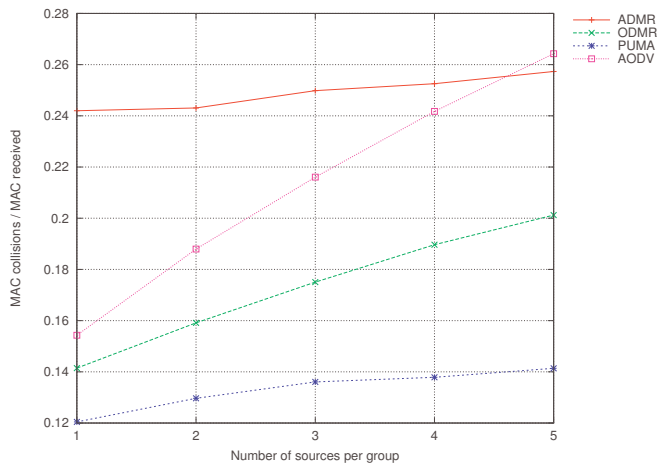


Fig. 8. Collisions / received packets ratio. 1 packet generated every 10 seconds, 6 active groups with 3 receivers per group with new timers.

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