Maximum Amount Shortest Path (MASP) routing protocol implementation in ns-3

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ABSTRACT
In this work, we present an implementation of the Maximum Amount Shortest Path (MASP) routing protocol in ns-3. The main contribution of this work is to give the detailed and precise implementation of MASP. Additionally, performance evaluation from the view point of spatially unbalanced energy consumption is discussed.

Keywords
Routing protocols, WSNs, energy efficiency, constrained mobility, AODV, DSDV

1. MASP ROUTING PROTOCOL
Spatially unbalanced energy consumption among sensors is the most important issue in Wireless Sensor Networks (WSNs). This uneven energy consumption can significantly reduce network lifetime. The use of sink mobility with constrained paths and decreasing the message flood by limiting the flood area can help to improve the energy efficiency in WSNs. Maximum amount shortest path routing protocol (MASP) is an efficient protocol using this idea. MASP [3] is proactive (table-driven) in nature and tries to collect the largest amount of data using as least energy as possible. In a typical MASP topology there is one or more mobile sinks. The mobile sinks move along constrained paths in a field of randomly distributed static nodes. The static nodes that have direct communication with a mobile sink are known as subsinks. The rest of static nodes that do not have a direct communication with any mobile sink are known as member nodes. Only subsinks can communicate directly with mobile sinks. Member nodes must send their data to a subsink first to deliver their data to the mobile sink. The data sent to a subsink is queued there until a mobile sink in range collects the data. Additionally to this subsink mechanism, MASP divides the total area into independent routing zones to limit the messages flood. Zone division and data collection are achieved during multiple rounds. When a mobile sink goes back an forth to the beginning of its trajectory, we say that it has completed one loop (one round). The first two rounds divides the deployed nodes into independent zones to construct the nodes routing tables. Data collection takes place in the 3rd round.

2. MASP MODULE FOR NS-3
The relationship between all the classes implemented for MASP can be observed in the Figure 1. As a general rule, any protocol implemented in ns-3 must have one main class that extends from ns3::Ipv4RoutingProtocol class. In our implementation that class is ns3::masp:: MaspRoutingProtocol. Multiple classes extend from the ns3::Header class to create all the control packets in the protocol. Routing tables are managed in every node by an instance of the class ns3::masp::RoutingTable where multiple instances of the class ns3::masp::RoutingTableEntry are stored. The class ns3::masp::RangesTable controls and saves all the information related to times when subsinks are in range of a mobile sink and other calculations. The entries in the range table are made using the ns3::masp::RangesTableEntry class. Finally, subsinks packet queues and their entries are handle by the classes ns3::masp::PacketQueue and ns3:: masp::QueueEntry respectively. The queues implementation is similar to the one described in [4].

3. SIMULATION SETUP AND ANALYSIS
We conducted experiments using the latest available version of ns-3 (3.24.1). We used a single mobile sink moving at the bottom of a 400m x 200m rectangular area with constant speed of 5 m/s. Our seed value is set to 15 with a run value of 7 (random variables control). All the deployed nodes are using the wifi 802.11b standard with a max range set to 52m in the propagation loss model. Data packets size are equal to 1029 bytes. We used a shortest path method (AODV) as a target of comparison. The default parameters described in [1] are used for the experiment of AODV. Our MASP implementation uses the following essential parameters: number of zones = 3, half round time = 80 seconds. While the application data generation rate in the nodes can be configured with different settings in our experiments, the subsinks always transmit the buffered packets in the queues with the data rate of 5 mbps. Additionally, application data
is only generated during one second in *round 3*. Each application have a start time with the deviation of 0.002 seconds between nodes to avoid ARP collisions in the data collection phase. We considered a data collection phase of only half round. Figure 2 shows the average energy consumed by MASP and AODV with an increasing number of nodes and their maximum and minimum energy values. We set the nodes with the data generation rate of 20000 bps. Nodes have the initial energy of 3000 J with radio current set to 0.0174 Amp for packets transmission (Only packets transmissions consume energy). In our experiments, more energy is consumed by AODV. Nodes using AODV spend most of their energy to flood *hello* messages used to keep routes updated. Data packets are forced to pursue the constantly moving sink destination. On the other hand, MASP is aware of the route to the mobile sink beforehand. Therefore, packets do not need to pursue the mobile sink and wait in the subsinks until the mobile sink collects them instead. In AODV, as the number of nodes increases, packets stop being forced to use a single route and have more options to reach the mobile sink. In other words, the same routes are used less frequently and packet transmissions are distributed more evenly among nodes. However, collisions are still frequent because all the nodes within the range of the mobile sink send data to it. In MASP, collisions are existent but less frequent because the area is divided into multiple zones and subsinks in each zone send data to the mobile sink during the predefined time period. As seen in the Figure 2, it is clear that MASP have larger range between its min / max energy consumed than AODV. This is mostly because subsinks consume significantly more energy than non subsink nodes. Further experiments are possible using our code available at [2].

**Figure 1: MASP class diagram**

**Figure 2: Average Energy Consumed with Maximum and Minimum Energy consumed**

4. CONCLUSIONS

In this abstract we briefly described the implementation of MASP in ns-3. We presented a single experiment evaluating the energy consumption performance against AODV. Further experiments are possible using the current implementation. We are currently working on adding more variables.
to the experiments and comparison with further protocols.

5. REFERENCES


In a typical MASP topology of wireless sensor networks, there is one or more mobile sinks. The mobile sinks move along constrained paths in a field of randomly distributed static nodes. The static nodes that have direct communication with a mobile sink are known as “subsinks”. The rest of static nodes that do not have a direct communication with any mobile sink are known as “member nodes”. Only subsinks can communicate directly with “mobile sinks”. Member nodes must send their data to a subsink first to deliver their data to the mobile sink. The data sent to a subsink is queued there until a mobile sink in range collects the data. Nodes select their subsink destination based on a process called member requirement calculation. In this process the best subsink is selected based on its transmission time with the mobile sinks (overlapping transmission times of other subsinks are also considered).

Additionally to this subsinks mechanism, MASP divides the total area into independent routing zones to limit the messages flood. Zone division and data collection are achieved during multiple “rounds”. When a mobile sink goes back an forth to the beginning of its trajectory, we say that it has completed one loop (one round). Figure 1 shows the result of round 1. Different colors correspond to different zones. Subsinks are depicted by double-lined circles. Summarizing, in MASP the first two rounds divide the deployed nodes into independent zones to construct the nodes routing tables and the selection of the subsink destinations. Data collection takes place in the 3rd or more consecutive rounds.

We developed a full implementation of the MASP protocol in ns-3. The first implementation of this protocol used OMNET++ and assumed the precise synchronization of the clocks in all the subsinks to send their data to the mobile sink when in range. This, however implies difficulties in a real implementation because the internal clocks in each node can easily be desynchronized by external factors. Our implementation use a poll mechanism in the round 3 to trigger the data transmission between the subsinks and the mobile sinks. MASP zone division and a subsink - queue mechanism provides an even energy variability among the nodes when compared to AODV and DSR protocols.