Mobile Agent and Client/Server Data Dissemination in Wireless Sensor Networks

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ABSTRACT: *The purpose of the data dissemination in wireless sensor networks is to send any type of information (data or query) to all nodes concerned by this information, while minimizing the number of transmission nodes and the cost of energy. Data dissemination is considered as a main phase of energy consumption in the communication of Wireless Sensor Networks. Hence the way to eliminate redundant data traffic and reduce communication cost are the main challenges of the data dissemination. Depending on how to collect data and process them, we can distinguish in this article the Client/Server based data dissemination protocols, and the Mobile Agents protocols.*

Keywords: Data Dissemination, Mobile Agents, Data Aggregation, Client/Server, Data Collection, Data Fusion

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1. Introduction

A sensor is a small device capable of performing simple measures on its immediate environment. The use of these sensors is not a novelty; they have long been used in fields such as aeronautics and automotive industries.

What is innovative is the ability of these sensors to communicate in radio (wireless) nearby other sensors (few meters) and for some boarding of processing capacity (CPU) and memory. We can build networks of wireless sensors (WSNs) that work on a fairly large extent. These sensor networks raise a growing interest from the industrial and civil organizations where monitoring and recognition of physical phenomenon is a priority. For example, these networked sensors can monitor a defined area to detect the appearance of a given phenomenon (vibrations, linear motion ...) or measure a physical condition such as temperature (fire detection in forests) or pressure. In many crisis management scenarios (earthquakes, floods ,...) these sensor networks can provide a better knowledge of the field to optimize the organization of relief, or even provide scientific information specifically on the causes of a particular physical phenomenon.

Common usage scenarios envisage thousands of sensors that can be dispersed to monitor sensitive areas. The resistance to scale will be a crucial factor. Added to these difficulties, that the sensors have very limited resources in terms of bandwidth and operational autonomy since in most deployment scenarios, the sensors operate with small batteries. This limitation of resources necessitates large scale of cooperation where interactions between sensors can be extremely complex. This requires the establishment of a protocol at the middleware layer for the dissemination and retrieval of data in an efficient manner.

The purpose of the data dissemination is to send any type of information (data or request) to all nodes affected by this information, while minimizing the number of transmission nodes and the cost of energy [1]. Data dissemination is considered as a main phase of energy consumption in the communication of WSNs [2]. Hence the way to eliminate redundant data traffic and to reduce communication costs are the main challenges of the data dissemination. On applications of WSNs such as environmental monitoring, data dissemination is very important. Indeed, it is known that the ineffectiveness of data dissemination (such as blind broadcasts) causes broadcast storms and blocks all communications in the network [3].

In most WSNs, sensors are deployed in an area to extract environmental data. Once the data collected by multiple sources (multiple sensors in the vicinity of the event captured), they will be transmitted via multiple hops to a single destination (sink). This, coupled with the fact that the information collected by sensors neighbors is often redundant and correlated, and that energy is the most precious resource, requires the use of data fusion. Instead of transmitting all data to a central node for processing, the data is processed locally and only aggregate information is returned to the sink. Data fusion reduces the number of packets to be transmitted via the sensors, and therefore energy consumption and bandwidth are also reduced. Its advantages are evident, especially in a large-scale network.

Multiple approaches have been proposed for collecting data being sensed in WSNs in a flexible, reliable, and efficient manner. The most relevant can be classified into two categories

Client/Server based Data Dissemination The sink sends queries to sensor nodes, each sensor node will then process the request and send the desired data individually to the sink which will process and aggregate it.

Mobile Agent based Data Dissemination The sink dispatches one or more mobile agents to sensor nodes. This agent will carry the code for data processing. In this way, the data will be aggregated and processed locally at the sensor nodes, then the agent will collect the data already processed to send it to the sink

1.1 Overview of Paper

In the next section we define the classical Client/Server paradigm and then illustrate it with four protocols in WSNs. After that; we will see the Mobile Agent paradigm by exposing its advantages and weaknesses and examine four MA based data dissemination protocols in WSNs. Then; we compare the two paradigms by doing simulations of one protocol from each paradigm. Finally we finish with our conclusion

2. Client/Server based Data Dissemination

The WSNs are a typical distributed environment and the Client/Server paradigm is one of the models adopted in distributed environments [19]. In this paradigm, a server offers a set of services, resources, and programs for the execution of services. The client (which is a sink node in WSNs) requests the execution of a service. In response, the server (which is a sensor node in WSNs) processes the service request by running the corresponding program and accessing resources involved in the server.

Despite the unreliability and the limited bandwidth of wireless links used in sensor networks, in addition to the constraint of energy that is crucial in WSNs, protocols using the Client/Server paradigm in this type of networks are numerous [5][6][15]. For example, the DD Protocol [4] is one of the most used models in many works in WSNs.

2.1 DD

DD (Directed Diffusion) [4] is one of the first founders of data dissemination protocols in WSNs after flooding and gossiping [18].

In DD, the collector node sets, using a list of attribute-value pairs, a message which expresses the interested data. This message, called interest is diffused through the network to find the potential data sources. This release installs gradients in the network to guide data coming from sources to the sink. A gradient is a link response to a neighbor from which the interest was received; it indicates the direction to be followed by the data sent by the sensors. It is characterized by a value and a lifetime fields received in the interest.

When a sensor detects data that meet the received interest, it sends to all neighbors for which a gradient is set a data messageclassified as exploratory. When an intermediate node receives a new exploratory data, it inserts it into the data cache and sends it to all neighbors for which a gradient exists. When the collector node receives a new exploratory data, it sends a positive reinforcement message. It uses the data cache to forward the message to the neighbor who provided the first exploratory data. Each intermediate node repeats the same operation after receiving a message until it reaches the source. So the quickest way to provide the data path is reinforced between the source and the collector. Then the data will be collected, and sent through that strengthened path. Nodes can also send messages to negative reinforcement to remove unnecessary paths connecting the source to the collector. Periodical sending exploratory data enables network nodes to discover new more reliable paths and eliminate failed paths using rules of positive and negative reinforcement [4].

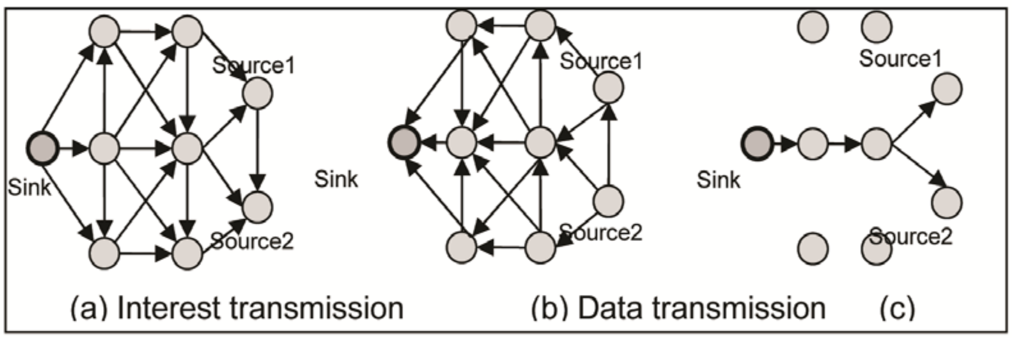

Figure 1. Directed Diffusion.

The DD resolution became like a foundation of many data dissemination protocols like MADD [8], AbDD [9] and IDDMA [17].

2.2 TTDD

TTDD (Two Tier Data Dissemination) [5] is a hierarchical dynamic protocol, choosing leaders according to their geographical positions by using a structure called grid. A grid is a set of equal squares, called cells covering the entire network. The tops of the cells represent points of dissemination. The node closest to a dissemination point is called dissemination node, which is a leader in the hierarchy.

TTDD assumes that when an event arises in an area, only one sensor is elected to represent it. The protocol also assumes that each sensor knows its location except the sink.

It uses a greedy geographical relay defined as follows:
When a sink wants a given data, it floods the local area to reach the closest dissemination node, which will become his immediate dissemination node (IDN). The IDN relays the query using the information of the upstream in each node, to reach the source. At the same time, the opposite itinerary is built, saving the identifier of the downstream to route the data later to the sink.

TTDD allows implementing a handoff mechanism to send the data to the sink, even if it moves. When the sink finds that the distance to his primary agent exceeds a certain threshold, it selects a new primary agent, and possibly a new IDN.

2.3 LBDD
LBDD (Line-Based Data Dissemination protocol) [6] is another protocol that supports mobility of the sink, and uses a virtual structure as rendezvous region to facilitate the dissemination process.

LBDD defines a virtual structure in the form of a band of width w, in the middle of the interest area. This band is also divided into groups of size g. Nodes positioned inside of the band are called inline-nodes. This band represents an appointments area for queries and data.

This protocol assumes that each node knows its geographical position and the coordinates of the interest area. With this assumption, the election of the inline-nodes is done easily. LBDD uses a geographic routing.

The operation of LBDD consists of two main steps:

• Dissemination: when a node detects a stimulus, the data is generated and sent to the nearest inline-node;

• Collection: to collect different data, the sink sends a request perpendicular to the strip. The first inline-node which receives the query will propagate it in both directions of the strip to attain the nodes with the required data. This will be then sent directly to the sink.

• To facilitate the data search, [6] offers two storage solutions within the band:

• Data is flooded within a group; this solution may cause a congestion problem.

• Data is stored at the leader of a group; this solution requires a periodic election of the leader to avoid overloading a particular node.

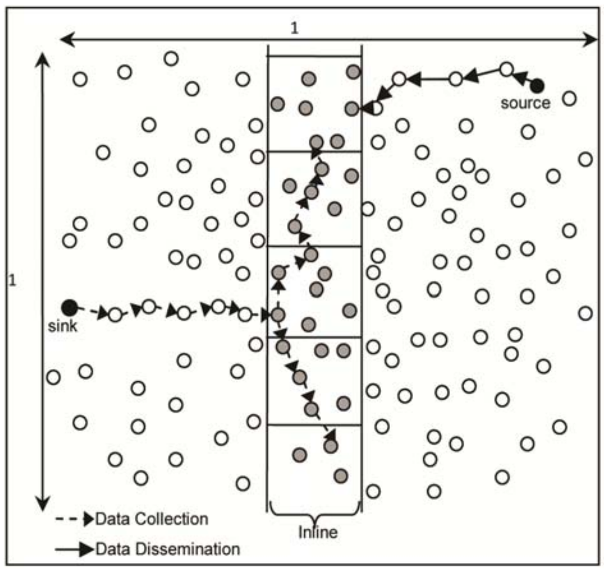

Figure 2. LBDD structure

LBDD offers also a handoff solution similar to the TTDD handoff mechanism

2.4 HexDD

In place of a rectangular grid, a Virtual Infrastructure Based on Honeycomb Tessellation Dissemination (HexDD) [15] uses a common hexagonal grid structure which is given away to surpass rectangular grid based approaches.

In fact ; unlike TTDD, it constructs a single combined grid structure for all possible sources. Geographical position-awareness of sensor nodes is necessary to construct the grid.

The HexDD goal is to prevent redundant diffusion of the sink's data queries over the entire grid by defining queries and data rendezvous lines (6 border lines) along the six directions following the edges of the hexagons. The border lines intersect on a the center hexagonal cell. Sensor data are sent towards the closest border line assuming a counter-clockwise direction and then propagated through the border line towards the center cell. The nodes on the border line replicate and store the data. Queries are also forwarded towards the center cell via the same mechanism.When a query meets a corresponding data stored on a border line node, the data is sent towards the sink through the reverse path. If the sink moves inside its current cell, there is no need for another process since the data will be forwarded to the same neighboring cell until sink leaves its cell.

But the main Drawback of this solution(like all rendezvous region based solutions) is hotspots in the nodes on the border lines and especially on the center cell which is the intersection of these lines

Protocol	Advantages	Disadvantages
DD	• Consumes less power than the flood due to the reinforcement of a single path. • Provides good latency due to choosing the best path to reinforce. • Allows a good scalability due to local interactions between neighbors (one-to-one) • The periodic retransmission of the interest and the data provides good robustness especially when mobility or failure of nodes. • Allows aggregation at each node. • Facilitates the maintenance of paths through the multipath.	• Cache treatment consumes a lot of energy and memory. • Large costs in establishing gradients due to flooding. • Network lifetime decreased, due to the periodic diffusion of interest and data. • Rapid depletion of the energy of the nodes in the strengthened path.
TTDD	• The grid structure facilitates scalability. • Energy conservation during the flood of local interest. • Fault tolerance due to information duplication in the neighbors of IDN. • Handoff mechanism prevents data loss due to the PA and IA. • Aggregation of requests and data in the case of multiple sinks. • Charge sharing between nodes by using a different grid for each source node.	• A grid for each source is very expensive in construction and maintenance. •The grid is based target, this involves the creation of new grid with every movement of the target.
LBDD	• Improve latency by traversing only half way to reach the data. • Handoff mechanism prevents data loss when the sink moves. • Preserves energy by directing queries and data directly to the band (no need to broadcast).	• Charge concentration at the band which generates energy depletion and saturation of memory of the nodes in the band. • No method for determining construction parameters of the virtual structure (w, g), especially when going to scale. • No mechanism for aggregating data on the band.
HexDD	• Avoid blind research of data and sink by using a rendezvous region • Handoff mechanism prevents data loss when the sink moves inside his hextant. • Preserves energy by directing queries and data directly to the closest border line (no need to broadcast).	• hotspots in the nodes on the border lines and especially on the center cell which is the intersection of these lines • Poor handoff mechanism; especially when the sink leaves his current hextant

Table 1. C/S based data dissemination protocols

3. Mobile Agent based Data Dissemination

The use of MAs in computer networks has many advantages but also some disadvantages, such as security and caching code in certain scenarios. Nevertheless, they are successfully used in various applications such as parallel programming, data collection, e-commerce and mobile computing. As described in [16], many inherent advantages (eg scalability and energy awareness) of the MA architecture make it suitable for WSNs than the client / server architecture. Indeed, mobile agents can be used to greatly reduce the communication cost, especially through low bandwidth by moving the processing function to the data rather than bring the data to a central processor.

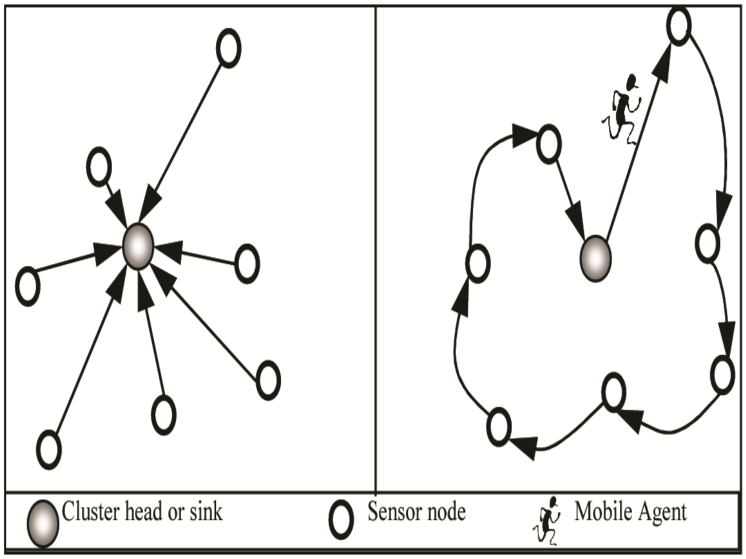

Figure 3. Client/Server and Mobile Agent architectures

3.1 MAWSN

Based on the principle that the communication cost to send an information using a long message is usually less than sending the same information using several short messages, the MAWSN protocol (Mobile Agent based Wireless Sensor Networks) [7] will perform several concurrent tasks associated with small amounts of data by a single packet transporting multiple queries, and concatenate the results in a single package to reduce the communication cost (Figure 4).

The context of application and design of MAWSN highlights some assumptions:

• The sink knows all sources nodes to be visited by the MA.

• The itinerary of a MA is already designed before dispatching the MA.

In this approach, the sink sends queries to multiple targets simultaneously via a mobile agent. The data in the target region are collected by the mobile agent on the sources one by one, and all combined tasks are executed one after the other, so that the entire process will take a longer time execution. If the quality of service requirements (eg, terminal latency) is not violated, especially if the target area is far from the sink node, the energy gain from this execution combination could be important.

MAWSN reduces redundancies and communication cost by 3 levels as shown in Figure 4, the sink node attributes to the MA the processing code (behavior) based on the need for a specific application. The code carried by the MA requires local processing of raw data sources at the nodes as requested by the application. This behavior reduces the amount of transmitted data by allowing only relevant information to be extracted and transmitted. It removes also spatial redundancies between sensors close to each other. Finally; concatenates the data from several small packets into a larger package to reduce communication costs

With the data concatenation, cyclic functions and communication cost of intermediate sensors can be reduced to increase the lifetime of the network. However, these energy savings can usually be obtained at the expense of the prolonged latency.

The MAWSN author proposed another mobile agent architecture combined with Directed Diffusion, MADD (Mobile Agent based Directed Diffusion) [8], trying to eliminate the maximum of assumptions (choice of target nodes and establishment of the MA visiting sequence) of MAWSN via the combination of Directed Diffusion approach with the mobile agent approach

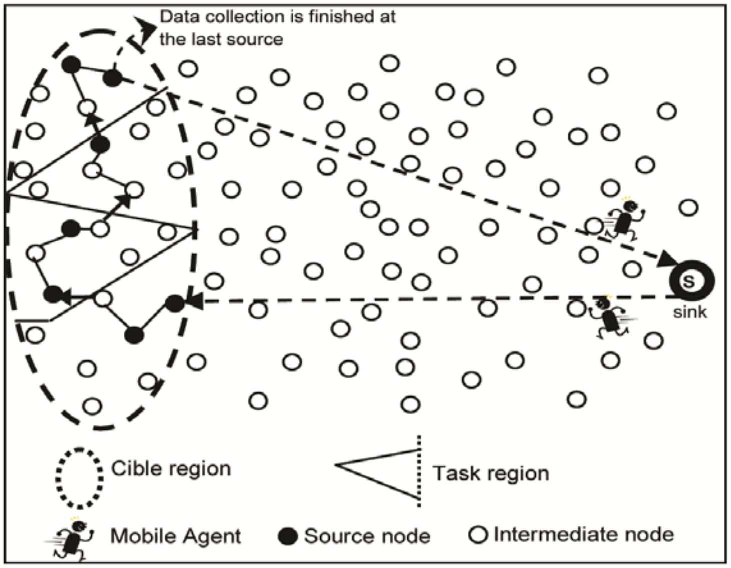

Figure 4. MAWSN architecture.

3.2 AbDD

The AbDD approach (Agent based Directed Diffusion) [9] uses the agent model combined with Directed Diffusion to ensure a better lifetime of the network.

In AbDD, each sensor node operates on the principle of localization, ie: each node knows its routing cost, the remaining energy, the cost of routing neighbors and their remaining energy, this is done by using a simple Hello protocol between neighbors [10]. Here are two types of agents: Stationary Agents (SA) and Mobile Agents (MA).

The SA resides in each source node. It monitors all activities of the node and updates its knowledge accordingly. The SA maintains the cache of interest, other models, his model and the initialization of routing costs.

Any node that receives a MA sets a gradient along the received path. If the node includes data corresponding to the value in its cache, it will be at the back of the sink along of the gradient. Otherwise it will add interest to its cache and send the MA to its neighbors. When the sink receives all the MAs discovered, it will process the data and provides a list of sequence of the source nodes that are in the area of the event and stores it in the MA with handling code for data aggregation. After the data collected from the last node in the list will be sent to the sink. The transmissions will use up the energy of the intermediate nodes. At each hop, it consults the models of other nodes and makes its decision to select the next hop (neighbor), based on the maximum battery level and the minimum path coast.

The MA in the first source node will clone himselves after the specified interval. Then, it collects the data, restores the timer, and migrates to the next source node. At each source node, the MA aggregates the sensory data, if possible. In this way, the MA continues his round to the sink to report the aggregated data. Upon arrival to the sink, it will pass the nodes sources data transported to the sink, and just after this he died. The number of times the timer is reset depends on the duration field of interest. Once the interest time expires, the MA removes all application code specified for all source nodes.

3.3 IDDMA

Improved Directed Diffusion based Mobile Agent (IDDMA) [17] is an improvement of MADD protocol that takes into accountthe choice of the shortest path (in number of hops) and the load balance between nodes during the first phase using a controlled Directed Diffusion protocol to set up multiple optimum gradients throughout sensor nodes to establish a low cost path betweensource nodes in the target region and the sink node

For that; IDDMA establishes a threshold energy (usually self-adjusted by the sink); and each node receiving a request from the sink and who have reached the remaining energy threshold will not participate in the data gathering process and will silently destroy the package containing the request of the sink. Also; at each node; there is a number of minimum hop count to select the shortest path (respecting the remaining energy threshold) between the sink and the target region. After that will come the data collection phase via mobile agent as done in MADD.

3.4 MLBDD

The MLBDD (Mobile Line Based Data Dissemination) approach [11] used a mobile agent solution [7] based on an appointment area inspired from the LBDD approach [6].

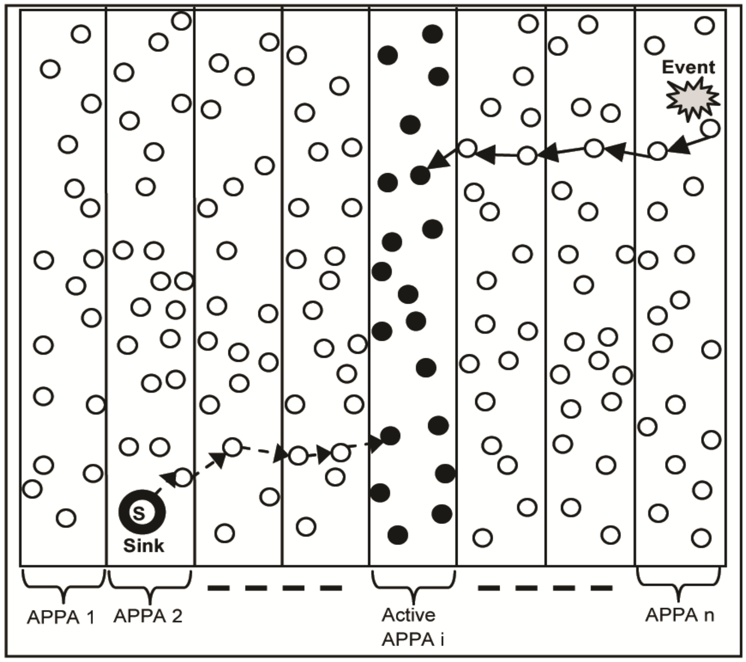

Figure 5. MLBDD architecture

The MLBDD interest area is divided into N rectangular bands. At a given time, only one band i (i • [1, N]) will represent the appointment area for the data collected by the sensor nodes and sink queries. After the lapse of a period T, the band i+1 will be activated as a current appointment area instead of the band i, and so on. This process is executed periodically to balance the charge among all the nodes (Figure 5).

When an event arises in the interest area, source nodes will generate the corresponding data and send it directly to the actual appointment area (APPA i). Since the nodes are equipped with a localization system, data packets will be routed to the appointment area using a greedy geographic routing [12] (each node will route the packet perpendicularly to the rectangular band).

When the captured data arrives at the first inline-node, it will be stored in its local memory or in its direct neighbors in turn.
To collect data, the sink creates a mobile agent (containing the query of the sink and the processing code of the data to be collected (aggregation code)) and send it directly to the activated appointment area (APPA i). The MA will carry a package containing several queries [7], where each query corresponds to a different application.

When the MA arrives at the first inline-node, it will choose another inline-node among its immediate neighbors to host the MA. The choice of the MA host will be in turn as it did for the choice of inline-node when storing data collected by sensors [13].

The first inline-node that receives the MA from the sink will broadcast the interest throughout the appointment area by using a multihop geographic routing. Then, each inline-node receiving this message and possessing the data referred to in the interest, will send a reply containing its location to the node hosting the MA.

After receiving the responses of inline-nodes, the MA will establish a logical visit sequence of these nodes, based on their geographical position.

Finally, like in MAWSN, the MA will browse the nodes by aggregating data as it collects them by eliminating the application and the spatial redundancies and then concatenates all the data into a larger package to reduce communication costs.

Protocol	Advantages	Disadvantages
MAWSN	• Reduce of communication cost through the use of MA and combined tasks. • Gain in-memory storage of the sensors through the use of MAs. • Aggregation of important data by eliminating spatial and appalication redundancies.	• High latency due to the combination of all tasks. • We must define in advance the visit sequence of sources and the path of the MA, which is not always possible especially on scaling. • Lack of robustness, for example in case of failure of a link or a node at the time of transmission of the MA.
AbDD	• Gain of memory storage of the sensors through the use of MAs. • Extending the life of the network using an energy efficient routing through the formula of the routing cost. • Allow adaptation to changes in network topology by periodically exchanging routing information through the use of Hello messages.	• The problem of overhead in DD in the first phase still appears in AbDD during the initial release of MAs and the establishment of cost tables. • Selection of the source nodes only once, so the sources will remain the same until the end of the task. However, the movement of the target and the change of the event can lead to new sources that will not be identified for the current task. • No method of construction of the visit sequence of source nodes.
IDDMA	• Fiable routing by eliminating nodes having no suffisant energy • Choosing FirstSource and LastSource depending on their distance from the sink saves communication energy. • Provides good scalability through dynamic decision of the MA itinerary.	• The problem of overhead in DD in the first phase still appears in IDDMA • Visit Sequence of source nodes decided by the choice of the closest source node does not ensure that the full path is the best (NP-hard problem).
MLBDD	• Reduce of communication cost through the use of MA and combined tasks. • Data Aggregation using MA • Increase the network lifetime by balancing the charge among all the nodes. • Establish a logical sequence of visiting nodes	• High latency due to the combination of all tasks. • Require a localization and synchronization systems.

Table 2. MA based data dissemination protocols

4. Performance Evaluation

To evaluate the performance and compare the two types of architectures (Client/Server versus Mobile Agent), we done simulations of the two protocols LBDD and MLBDD which are the two suitable protocols (from each architecture) for zcomparison. To do this, we used the GloMoMim simulator [14] (Global Mobile Information System Simulator).

4.1 Energy Consumption

According to the graphs in Figure 6, we find that the energy consumption increases when we increase the frequency of data creation. This is due to the increased traffic generated by the data dissemination and storage. However, the consumption of energy in LBDD is always higher than MLBDD; this is because LBDD disseminates data in the whole group in the area of appointments while MLBDD stores each data in a single node belonging to the appointment area.

We can also see that the energy consumption in the two approaches LBDD and MLBDD increases as the number of nodes in the network increases. Because, as more nodes there are as traffic increases between these nodes. However, LBDD energy consumption increased by 154,311 between 200 and 600 nodes, whereas it increased by only 87,371 in MLBDD. This is because LBDD uses diffusion for data storage while MLBDD uses diffusion for queries and MA. And since data packets are usually larger than the control messages and queries, the total LBDD energy consumption is higher than MLBDD.

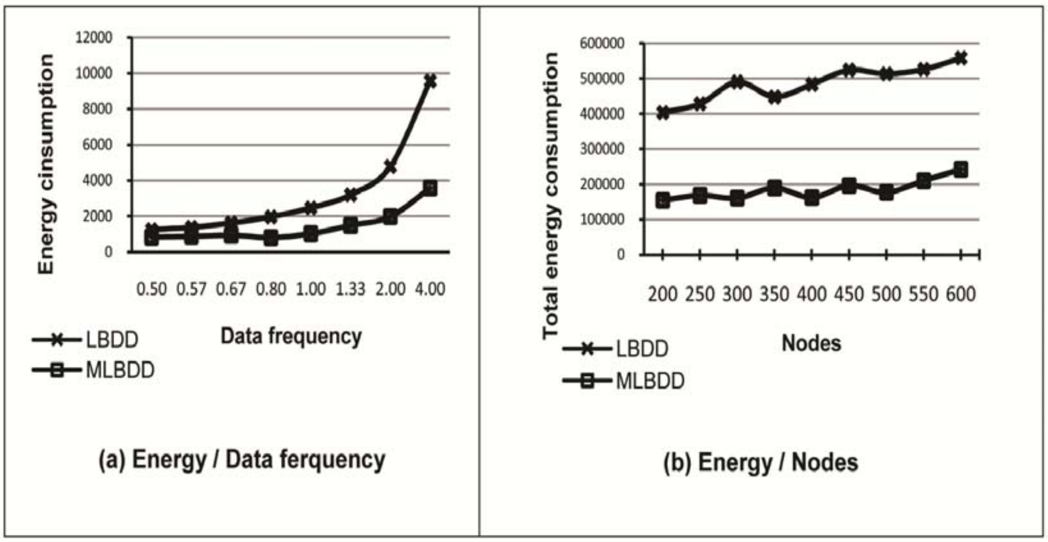

Figure 6. Energy consumption

4.2 Latency

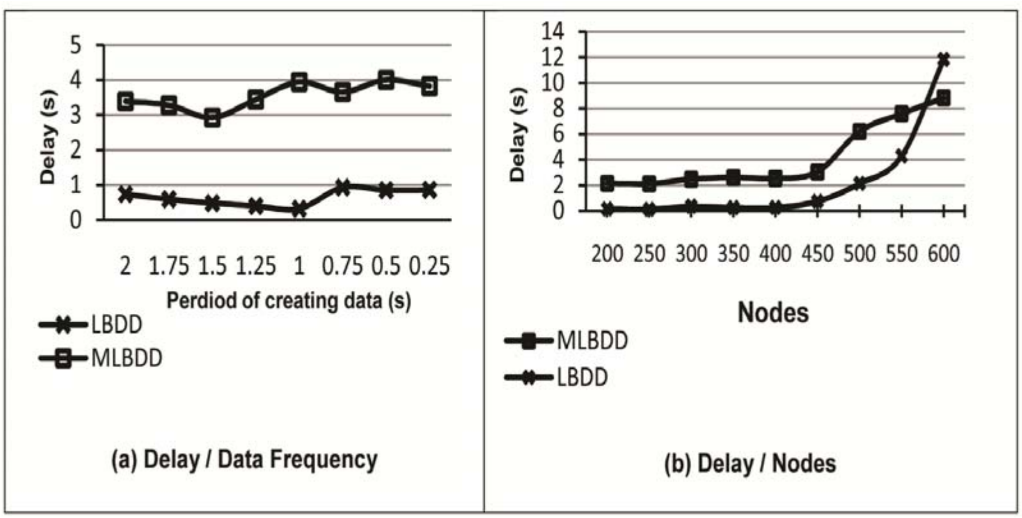

Figure 7. Latency

According to the graphs in figure 7, we note that more the load of the data and the nodes increases in the network, more the delay of collection increases. This is justified by the fact that the communication increases in the network and thus one will have more collisions between the nodes and more retransmissions and thus an increase of the deadlines. However in MLBDD the delay varies between 2.9 and 4 seconds. This is due to the use of the MA which makes a 1.5 seconds waiting for the collection of the answers of the inline-nodes having the desired data, in addition to the course of all these inline-nodes to collect the data concerned. But LBDD has a time considerably lower than MLBDD; because the collection in LBDD is done directly without diffusion neither makes an attempt nor browsing the nodes by MA

5. Conclusion

In this survey, we noticed that the conception of each data dissemination protocol is based on certain assumptions and is projected for specific applications on the network. In fact, the protocols LBDD [6], TTDD [5] and HexDD [15] are designed for a network with mobile sinks. On the other hand, LBDD [6] uses a flat architecture while TTDD [5] and HexDD [15] are based on a hierarchical structure. MAWSN [7] , IDDMA [17] and MLBDD [11] protocols proposed a solution based mobile agent for simultaneous multi-tasking applications, while DD [4] established local calls without having to determine the full itinerary between the sink and sources.

Simulations have shown that mobile agent approaches consumes less energy than C/S approaches; so MAs increase the network lifetime; but in the other hand, MAs have a bigger delay of response than C/S approaches. This makes Mobile Agent approaches not suitable for real-time and emergency applications and promotes then the Client/Server approaches for these type of applications

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