International Journal of Sciences & Applied Research

www.ijsar.in

Improved Routing Performance in Sensor Networks Using Virtual Coordinates (Survey)

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Abstract

In recent years, wireless sensor networks (WSNs) have a lot of care in both research and application fields. A major goal of researches in WSNs is to efficient data management techniques which are needed in Wireless Sensor Networks (WSNs) to stabilize issues related to limited resources, e.g. energy, memory, bandwidth, as well as limited connectivity.

Distributed Hash Tables (DHTs) over WSNs is a new routing model promises several advantages over conventional routing protocols. In this paper, we present a survey about using DHTs in WSNs, especially routing protocols techniques using DHTs over WSNs such as Virtual Ring Routing (VRR) & Virtual Cord Protocol (VCP). Furthermore comparing them through their scalability, energy-efficient, and data storage/lookup efficiency.

Keywords: Virtual cord, data management, failure tolerant, data replication

Introduction

As any other new scientific branch, the Wireless Sensor Networks (WSNs) became real world applications in the last years after it was purely academic research. Nevertheless, many of the original research issues still apply [1]. Between all the concepts of WSNs routing has concerned many research projects.

A wireless sensor network (WSN) consists of either several hundreds or thousands of nodes, each with very limited processing, storage, and communication capabilities [4]. Each node needs to communicate with its nearest neighbors in order to optimize energy efficiency. This includes the need to solve problems with high dynamics joining and leaving nodes protocol.

Over the last years, many routing protocols have been developed in the domain of WSNs. But still most practical approaches depend on standard Mobile Ad Hoc Network (MANET) protocols such as Ad Hoc on Demand Distance Vector (AODV) [1,5], Dynamic MANET On Demand (DYMO), or Dynamic Source Routing (DSR) [3,6,8]. On the other hand, the development of WSNs offers new capabilities that request different routing techniques and approaches.

Distributed Hash Tables (DHTs) used to find optimal paths towards the data and distribute these data over a large number of peers [4]. This operation is supported by hashes, i.e. virtual addresses. This paper we

will explain and analyze the advantages of using virtual addressing schemes in WSNs.

Actually, a number of proposals have been made that are based on virtual addresses for routing or data storage [4,6]. Motivated by studies on dynamic address allocation techniques that do not scale well in sensor networks, two objectives in this paper have been addressed:

1- Efficient routing towards clearly identified data items and

2- Fault tolerance, frequent node failures.

Both problem domains are being addressed by recent Distributed Hash Table (DHT) based approaches for data management in WSNs. In general DHTs solutions can be classified in three categories [1,6] : -

- Real location based.
- Virtual location based.
- Location independent.

One of the best routing protocols to be used in WSN is the geographic routing. Using GPS or any other means of self-localization can be used to collect the required geographic coordinates. Geographic Hash Tables (GHTs) hash keys into geographic locations, so the data items are stored on the sensor node geographically nearest the hash of its key. For routing, protocols such as Greedy Perimeter Stateless Routing (GPSR) [6,8] are used that use the physical location of nodes. Unfortunately, geographic routing does not ensure correct & enough results in all topologies. Problems with dead ends and costly recovery procedures make these approaches suitable for selected application scenarios only.

Most recent approaches for data management and routing in WSNs rely on virtual coordinates. Inspired by DHTs and bringing this idea down to the underlay, efficient routing paths can be maintained together with the capability to store information and data in a DHT like system [4]. The Virtual Ring Routing (VRR) appears as the first solution in this field [2]. The design of VRR is taken from Distributed Hash Table (DHT) overlays but VRR is a network routing protocol. Whereas DHTs assume an underlying network routing protocol that provides connectivity between all pairs of nodes, VRR is implemented directly on top of the link layer and provides both traditional point-to-point network routing and also DHT functionality: it balances the load of managing hash-table keys across nodes and routes messages sent to a key to the node responsible for managing the key [2,4].

Because that the Virtual Ring Routing (VRR) never floods the network and uses only location independent identifiers to route so it is considered as unique technique [2,4]. Nodes are organized into a virtual ring ordered by their identifiers and each node maintains a small number of routing paths to its neighbors in the ring. The nodes along a path store the next hop towards each path endpoint in a routing table. VRR uses these routing tables to route packets between any pair of nodes in the network: a packet is forwarded to the next hop towards the path endpoint whose identifier is numerically closest to the destination. The paths between virtual ring neighbors are setup using this algorithm.

VRR is made to be helpful and offer the service of routing over any link layer technology but this paper focuses on wireless ad-hoc environments [2,5]. DHT functionality is useful in these environments because it can be used to offer scalable network services in the case of nonexistence of servers. Furthermore, VRR addresses some performance issues with previous wireless routing protocols. VRR does not flood and it does not use location dependent addresses so it performs with the optimal path across a wide range of environments and workloads. Proactive wireless routing protocols flood on topology changes and reactive protocols flood to discover routes. Hybrid protocols perform scoped floods on topology changes and flood to discover routes to nodes in other regions of the network. Previous protocols that do not

flood use location-dependent addresses to route, which has some disadvantages. Location-dependent addresses can change with mobility and, in some protocols, with congestion and failures. These changes can result in losses and increased congestion, and usually require mechanisms to lookup the location of a node given a fixed identifier [2,10].

Virtual Cord Protocol (VCP) is one of the new protocols inspired by DHT, it is efficient and virtual relative position based routing protocol used in sensor networks. VCP exploits virtual coordinates to ensure the efficient, data management and failure tolerant routing VCP interconnects all nodes in the sensor network through a virtual cord. The main operations of VCP are similar to a DHT. It provides the data managing support using DHT services.

VCP also provides means for efficient resource and service discovery [1,3,5]. In exact, VCP exploits the inherent use of a DHT to organize data in the network together with indirections to store and to retrieve service locations in a publish/subscribe manner [7,9]. Node providing services publish this information in the virtual cord by means of hashing the information to a particular destination and storing the node's location at that destination. Then, nodes may use (subscribe to) the service by hashing the service again, retrieving the service's location (i.e., following the indirection), and finally accessing the service. However, a separate overlay is used in this solution that requires additional effort for underlay routing. This paper shows the applicability of VCP for service discovery and efficient routing in sensor networks [1,3,5,9].

The goal of this survey is to focus and explain the benefits of virtual coordinate based routing schemes especially VCP in WSNs. Therefore, we will compare the routing performance of virtual address based protocols, while VCP is our goal we compare it with VRR and a typical ad-hoc routing protocol (DYMO). This work will be to prove that VCP routing performance is better than the DYMO & VRR especially when there are node failures. Though, in case of node failures, VCP proves its strengths of efficient cord management.

So that the survey will focus on optimal routing techniques which are one of the main factors to solve the challenging topics in this domain which still appear as follows.

1- Energy efficient (power management).

2- Data management techniques (Data storage/lookup).

3- Scalability & Efficient and failure tolerant routing.

4- Self-organizing and cooperative.

Prelated work

DHTs is an underlying network routing protocol that provides connectivity between all pairs of nodes, DHT-based approaches for data management in WSNs can be classified into three main categories: real location-based, virtual location-based, and location independent [1,6]. DHTs hash keys into geographic locations; therefore every data item is stored on the sensor node geographically close to the hash of its key.

a. Virtual Ring Routing (VRR).

Virtual Ring Routing (VRR) Fig.1 [2,7] is a new network routing which is inspired by DHTs. It is applied on top of the link layer. It identifies the nodes through a unique key. This key is a location independent integer value.

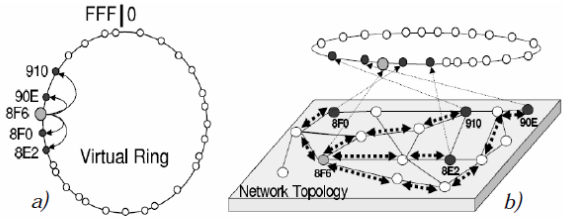

Fig. 1 . Relationship between the virtual ring and the physical network topology

VRR provides both traditional point-to-point network routing and also DHT functionality; it organizes the nodes into a virtual ring and orders them by increasing identifiers. For

routing purposes, each node maintains a set of cardinality r of virtual neighbors that are nearest to their node identifier in the virtual ring. The nodes also keep a physical neighbor set with the identifiers of nodes which it can communicate with it directly. On the other hand, VRR provides both traditional point-to-point network routing and DHT routing to the node responsible for a hash table key.

VRR is using a quite simple forwarding algorithm. VRR picks the node with the identifier closest to the destination from the routing table and forwards the message toward that node [2,6]. One of the most common problems of such protocols is that the adjacent nodes in the virtual ring may be geographically very far away in the real network. So, forwarding to the nearest node can result in a very long path. Furthermore, the scalability is a subject because when the network gets larger, maintaining routing tables when increasing size is one of the main needs. VRR has three operations: forwarding, node joins, node and link failures [2].

VRR was designed to provide consistent routing to the node responsible for a key with high chance even with node mobility and failures. It uses local failure discovery and assured failure notification mechanism to detect node and link failures quickly and with low overhead. Also VRR provide a fixed node identifiers and independent of the topology so it does not need to transfer hash table data across nodes when they move.

b. Virtual Cord Protocol (VCP).

Virtual Cord Protocol (VCP) is a routing protocol designed for efficient data management in sensor networks [1,3]. VCP is one of the main examples that show the benefits of using virtual coordinates to increase the efficiency of routing. Also, the protocol supports data replication to improve the failure performance. VCP exploits the concepts of DHTs [1] to combine data management with effective routing in sensor networks. The idea of VCP is to arrange the nodes in the network by forming a virtual cord. For ensuring an efficient and failure tolerant routing and data management, Routing is organized by exploiting information about the physical neighbors for greedy forwarding so that the topology of the cord must not be optimal in any sense. However, the cord ensures a connection between any two nodes.

VCP uses the hash function to create values in a predefined range [S, E] and each node maintains a part of an entire range in the network [3,6]. The routing mechanism depends on two concepts [10]: First, the virtual cord path can provides a path to all destinations in the network. Second, greedy routing performed toward the destination by using available neighborhood information.

The setup depends on an initial node. The new joining node detects the local neighbors by means of a hello-exchange message. Using the received information about the current state of the cord helps the new node which can join the cord by creating a new address and updating the routing table from its two adjacent virtual cord neighbors [1,3,7]. Routing is made by using available knowledge about the direct neighbors. Shortcuts can be used to route towards the destination.

Every node joins the VCP network must set three important variables: its position, predecessor, and successor in the virtual cord [1,3,9]. Each node regulates these values based on the positions of its neighbors. One hello message from the neighboring nodes is sufficient to set these parameters.

c. DYMO protocol.

DYMO protocol is one of the most recent reactive routing protocol, which is developed in the scope of the MANET working group of the Internet Engineering Task Force (IETF) [6,7].The first approaches to efficient the routing especially with the routing protocol AODV was the basics that helps to improve DYMO protocol. The main goal is to simpler design,

helping to lower the nodes' system requirements and to make the protocol's implementation simple and easy.

DYMO provides improved features, like covering possible MANET-Internet making a gate-way scenarios and applying path accumulation[7], and it keeps proven mechanisms of other previously explored routing protocols, for example the use of sequence numbers to impose loop freedom.

Discussion

Basically, the goal of this paper is to highlight the benefits of virtual coordinate based routing protocols in WSNs to efficient and failure tolerant routing in sensor networks. Therefore, we compared the routing performance of virtual address based protocols, in particular VCP and VRR with each other and with a typical ad hoc routing protocol (DYMO).

Thus the results clearly shows the advantages of virtual coordinate based approaches compared to classical routing protocols. Both VCP and VRR show a comparable performance especially in the optimal case, i.e. no node failures, on the opposite DYMO result.

Fig.2. [1] shows Delay performance of VCP, VRR, and DYMO in the grid scenario: depicted is the latency as observed by the application normalized to the path length. Fig.3. [1] shows MAC layer collisions per date packet sent for VCP, VRR, and DYMO in the grid scenario.

Although VRR performs well because of its unique features; that it does not require network flooding or translation between fixed identifiers and location-dependent addresses, but in the node failures case, VCP explained its strengths of efficient cord management and routing techniques over the other two protocols Fig.4. [7] shows the success rate and number of MAC collisions for the grid scenario. VCP deals with node failures with an efficient way compared to other routing protocols like VRR and DYMO, this because of its low maintenance overhead.

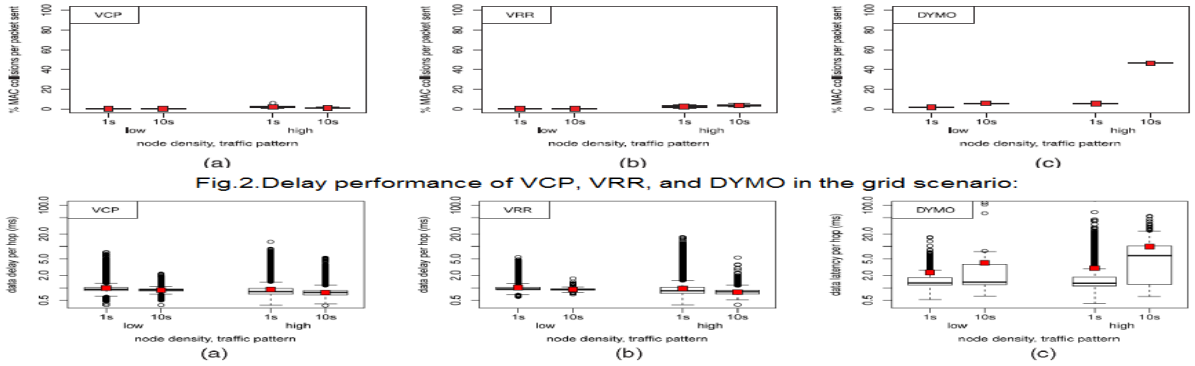

Fig.2.Delay performance of VCP, VRR, and DYMO in the grid scenario:

Fig.3. MAC layer collisions per date packet sent for VCP, VRR, and DYMO in the grid scenario

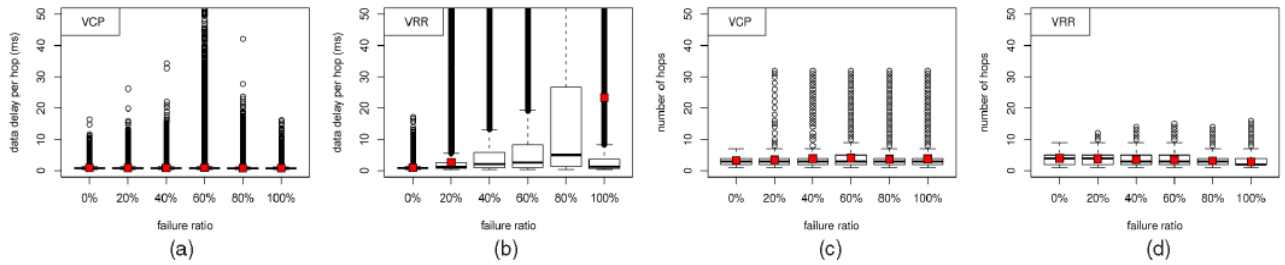

Fig.4. Failure performance

Conclusion and future work

Although routing protocols in sensor networks is a new area of research, but rapidly growing set of research results. In this paper, we presented a survey of three main routing techniques in wireless sensor networks VCP, VRR and DYMO. The simulation performance results provide us with initial evaluation for the protocols mentioned; we measured the impact of the network traffic load, potential node failures, and density. The comparison between the routing protocols, VCP and VRR, with a typical ad-hoc routing protocol (DYMO) clearly shows the advantages of virtual coordinate based approaches compared to classical ad-hoc routing protocols.

Based on these results and taking into consideration the capabilities of virtual address-based protocols to manage data using an application-specific hash function, we conclude that virtual coordinate-based approaches are better suited for WSNs, especially if these networks are dynamic and suffering from node failures.

Finally, the capabilities of VCP dealing with failure performance shows the high quality of data management and routing in sensor networks, which means that this protocol may be enhanced to support data replication to improve the failure performance.

Future work tries to implement VCP on real sensor nodes in a real environment to verify its applicability on resource limited sensor nodes. And to make a new researches of the suitability of VCP for content replication in sensor networks.

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