ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 3, May-Jun 2013, pp.798-804

Performance Analysis of Collection Tree Protocol in Mobile Environment

Bijal Chawla*, Dhaval Patel, Chandresh Parekh***, Miren Karamta****, Dr. M B Potdar*******

*(Department of Wireless Mobile Computing, Gujarat Technological University, Gujarat, India)
** (Department of Wireless Mobile Computing, Gujarat Technological University, Gujarat, India)
*** (Head of Department in Electronics and Communication, Government Engineering College, Gujarat, India)
**** (Project Scientist at Bhaskaracharya Institute for Space Applications and Geo-Informatics, Gujarat, India)
***** (Project Director at Bhaskaracharya Institute for Space Applications and Geo-Informatics, Gujarat, India)

ABSTRACT

Wireless Sensor Network (WSN) is growing over widely and with its growth more emphasis has been seen in mobile sensor nodes. Collection tree protocol (CTP) is one of the most promising data collection tree protocol. CTP is very efficient routing protocol and it forms the basis for other protocols. CTP has a wide range of applications in static WSN. In this paper we will analyze the performance of CTP in static and mobile environment. We will also identify important factors that contribute to the degradation of CTP's performance in mobile environment. The paper will also show the solution based on the analyses which results in increased data delivery ratio without any control overhead.

Keywords-*Collection Tree Protocol (CTP), Data Collection, Routing Protocol, Wireless Sensor Network (WSN)*

I. Introduction

Since a long time in history of Wireless Sensor Network (WSN) there is a large number of data collection protocols that has been used. Among these, the Collection Tree Protocol (CTP) is widely regarded as the reference protocol for data collection [1]. Currently TinyOS is one of the operating system which supports an implementation of CTP.

WSN has been growing rapidly and with its increasing growth mobile wireless sensor networks are becoming common. In mobile sensor networks there are mobile nodes which are moving. Due to these moving nodes network topology keeps on changing. Thus there must be routing protocol for such network that can transmit the data correctly and reliably to the sink node. As described previously CTP is one of the most promising data collection tree protocol. CTP is being very efficient in static environment and has large number of applications also. In this paper we will show that in mobile environment the performance of CTP is not as much effectual as compared to static environment.

We will also identify the important factors which are affecting CTP and are responsible for degradation of CTP in mobile environment.

II. CTP Modules

As shown in the Fig. 1 [1] there are three main logical software components of CTP: Routing Engine (RE), Forwarding Engine (FE), and Link Estimator (LE).

2.1. Routing Engine (RE)

Routing Engine is basically concerned with the sending and receiving of beacons. It also takes care of creating and updating routing table. Routing table consists of information related to the neighbors which comes helpful during parent selection in routing mechanism? This table is being updated on receiving beacons at a fixed interval. Apart from these routing table also consists of a metric which shows the quality of a link.

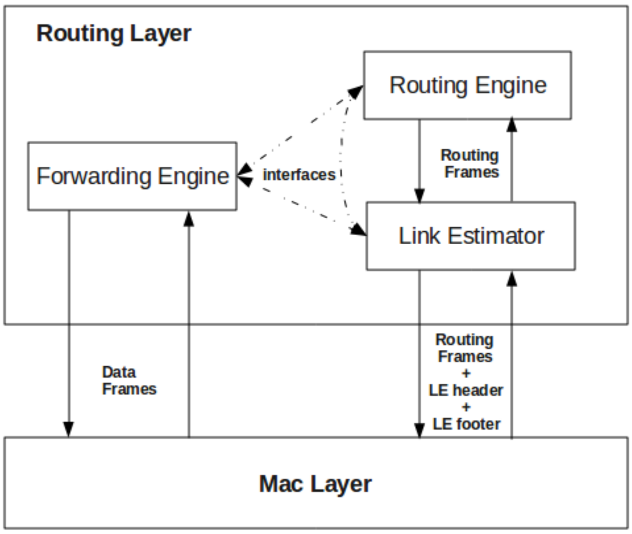

Fig. 1. Module Interaction and Message Flow in CTP

In CTP this metric is called ETX (Expected Transmission). A node having an ETX equal to n is expected to be able to deliver a data packet to the sink with a total of n transmissions, on average [1].

This ETX value is being exchanged between the nodes along with the beacons. While selecting a parent the node will compare its neighbor on the basis of ETX value and will select a node with the lowest ETX value as its parent.

2.2. Forwarding Engine (FE)

Forwarding Engine generally forwards data packets either from the application layer or from the neighbors. The FE is also responsible of detecting and repairing routing loops as well as suppressing duplicate packets [1].

2.3. Link Estimator (LE)

Link Estimator determines the inbound and outbound link quality of the neighboring nodes for 1-hop communication links. The LE computes the 1-hop ETX by collecting statistics over the number of beacons received and the number of successfully transmitted data packets [1].

Inbound metric is calculated as a ratio between the total numbers of beacon sent by a neighbor over the fraction of received beacon. While the Outbound metric is calculated as the number of transmission attempts required by a node to successfully deliver a data packet to its neighbor.

III. Key Challenges of CTP

2.4. Packet Duplicates

Duplication of packets occurs when a node receives a data packet, sends an acknowledgment packet but the acknowledgment is not received. Due to this the sender will send the data packet again and the receiver will receive it twice. This duplication will effect over number of hopes as duplication is exponential.

2.5. Routing Loops

Normally in parent selection a node will select a node with lower ETX value but if it selects an ETX value higher the previous one then the loop occurs. If the new route being selected contains a node which was a descendant earlier, then a loop occurs.

2.6. Link Dynamics

Periodic beaconing is being used in a protocol to maintain the topology and estimate link qualities. An efficient link quality estimation technique is vital for the performance of a collection protocol. The beaconing rate introduces a tradeoff between agility and efficiency: a faster rate leads to a more agile network but higher cost, while a lower rate leads to a slower-to-adapt network and lower cost.

IV. Advantages of Mobility

As we are working on performance based in mobile environment, the advantages of using mobility are as shown below [2]:

2.7. Long Network Lifetime

Due to the mobility we can have sensor nodes moving which will result in having transmission more disperse and energy dissipation more effective. Moreover when sink nodes are static we find that nodes near the sink get die sooner compared to other nodes. But if the nodes are mobile then this problem can be eliminated which will definitely increase the network lifetime.

2.8. More Channel Capacity

By creating multiple communication paths and the number of hopes a message must travel before reaching the destination, channel capacity is increased as well as data integrity can also be maintained using mobility.

2.9. Enhance Coverage and Targeting

Nodes are being deployed in a grid, random or any other regions. However, an optimal deployment is unknown until nodes start collection of data. Deployment of nodes in remote or wide areas, rearranging node positions is generally infeasible. However, when nodes are mobile, redeployment is easily possible.

2.10. Better Data Fidelity

When wireless channel is in poor condition, a mobile node is helpful to carry data to a destined point. The reduced number of hopes will increase the probability of successful transmission.

V. Implementation Details

We have used a simulator Castalia 3.2, which is designed especially for wireless sensor network. Castalia is based on OMNET [12] so we will be using omnetpp-4.2.2. The Castalia simulator for WSNs, for instance, provides a generic platform to perform "first order validation of an algorithm before moving to an implementation on a specific platform" [11].

The Table I will show some simulation parameters that we are going to use in order to determine and analyze the performance of the CTP in static and mobile environment.

Bijal Chawla, Dhaval Patel, Chandresh Parekh, Miren Karamta, Dr M B Potdar / International Journal of Engineering Research and Applications (IJERA)
ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 3, May-Jun 2013, pp.798-804

Table I: Simulation Parameters

Parameter	**Value**	**Unit**
No. of Nodes	100	Nodes
Dimension of Space	250 × 250	Meters
Simulation Time	30	Seconds
Deployment	uniform	-
Mobility Manager Name	Line Mobility Manager	-
Update Interval	100	Seconds
Speed	3	meters / second

VI. Simulation Results and Analysis of Existing CTP

The following are some of the important performance metrics that we will be using for the study of CTP's performance under mobile scenarios:

1. *Data delivery ratio:* It defines the ratio between the number of data packets successfully delivered to the sink to those sent by the source nodes.
2. *Control traffic:* It defines the traffic resulting from routing beacons in the network for establishing and maintaining the tree.
3. *Application level packet latency:* It is the time taken for a packet to travel from the source node to the sink node.

Now we will study some of the results that we have obtained during our simulations. In the following results we will be comparing the performance of CTP in static and mobile environment.

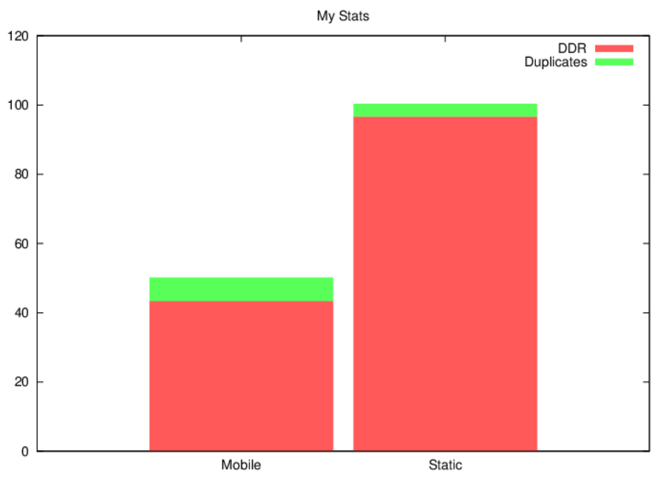

Fig. 2. Data Delivery Ratio and Duplicate packets

As shown in Fig. 2, the Data Delivery Ratio (DDR) with static nodes is 96.67% . It proves that CTP is very efficient routing protocol in static environment. The ratio of duplicate packets in static environment is 3.67%. While in mobile environment the DDR is very less compared to static which is just 43.33%. It means that when nodes are mobile very less number of data packets are being transmitted to the destination (sink node). The number of duplicate packets is also more in the mobile environment that is up to 6.83%. Due to mobility the acknowledgment (of the received packets) is not being received by the neighbor node and thus the node sends the data packet again and again which results in increasing number of duplicate packets.

Fig. 3 and Fig. 4 shows the control packets required to transmit in static and mobile environment. In static, the number of beacon packets transmitted and received is very less as compared to the mobile as shown in Fig. 3. The number of transmitted packets is also more in mobile as shown in Fig.4. It shows that in mobile environment the control packet overhead is being increased.

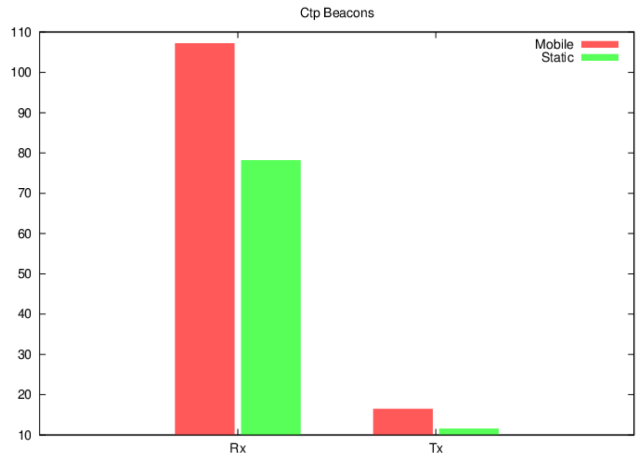

Fig. 3. Beacon packets transmitted and received

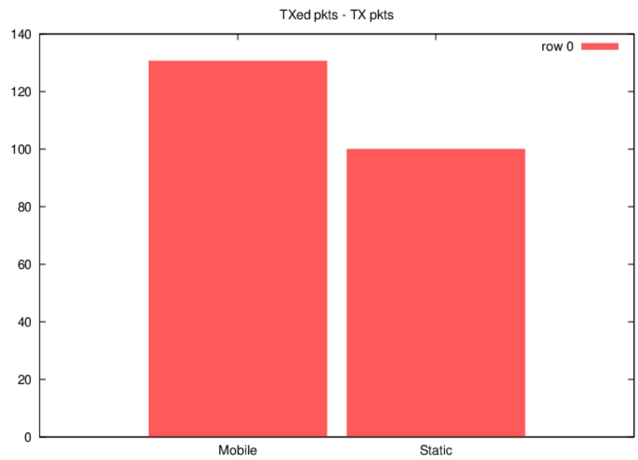

Fig. 4. Transmitted packets

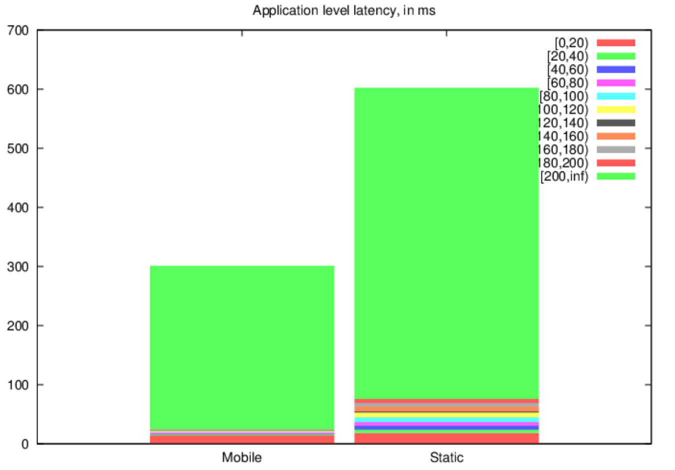

Fig. 5. Application level Latency

The end to end delay or latency is also an important performance metric for sensor networks. As shown in the Fig.5, latency for static nodes is compared with the nodes in mobile environment. The result shows that the average delay increased with the increase in node mobility.

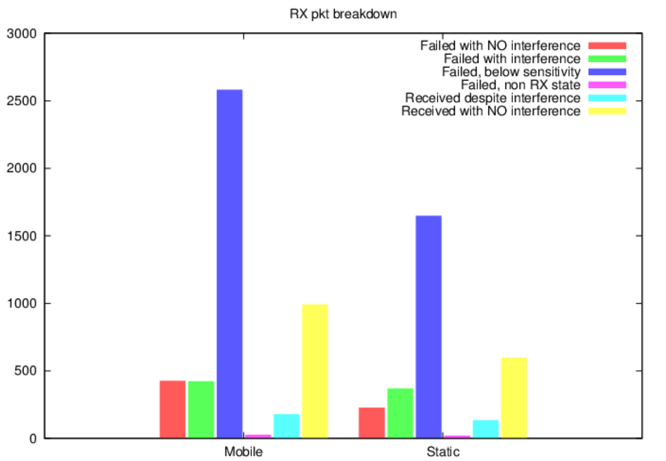

Fig. 6. Received packets breakdown

Fig. 6 shows that the ratio for the failure of the received packets is more in mobile as compared to static environment. From the received packet breakdown we can see that packet sending was failed because the signal was below the receiver's sensitivity level. This happens when node moves out of the range of a receiver.

VII. Solution

We will deploy a small number of static nodes in our network region with all other nodes mobile. This static node will have higher transmission range compared to other mobile node in order to have large coverage area. Due to this most of the area in network region will be covered out.

The static nodes are identified by special flag bit set namely static(S) in the Routing Frame [16] [18] [19]. Now every mobile node will have an entry of this static node's ETX in its link estimation neighbor table and routing table. The parent selection will now be carried out based on two criteria: static node and ETX. For parent selection, a node will find out first any static node in its neighbor and thereafter it will find the node with the lowest ETX value. Here the number of retransmissions is decreased as compared to previous CTP. The advantage of this mechanism is that it will increase the data delivery ratio with minimum control overhead. Due to some static nodes the network will have a backup infrastructure. The reliability of the network will also be increased as the packets are not dropped for not finding any route due to the changing topology with mobile environment.

Algorithm:

The routing algorithm for enhanced CTP is shown in the Fig. 7. As described in [16] [18] [19] there are some modifications that are made and the resultant algorithm is as shown below.

Algorithm Routing Algorithm for Enhanced CTP Protocol

```
Let minETX ← 0XFFFF
Let minETXForStaticNode ← 0XFFFF
Let Rn ← bestETXRoute
Let Rs ← bestStaticETXRoute
for RoutingTable[i]
if (minETX > RoutingTable[i].ETX)
    Rn ← RoutingTable[i].nodeId
    minETX ← RoutingTable[i].ETX
end if
if (minETXForStaticNode > RoutingTable[i].ETX) && (RoutingTable[i].isStatic)
    Rs ← RoutingTable[i].nodeId
    minETX for static node ← RoutingTable[i].ETX
end if
end for
if (Rs != Null) && (Rs.ETX < ETXthreshold)
    SelectedRoute ← Rs
else
    SelectedRoute ← Rn
end if
```

Fig. 7. Algorithm

The source node will find the required information from the routing table. Based on this algorithm, first criteria for a node will be to determine the surrounding nodes whether there is a static or mobile node. Thereafter, the source node will select its route for transmission. The source will prefer a static node first in order to transmit the data.

The second criteria will be to check the static node with lower ETX threshold. Reliability of the data is much more important in the mobile scenario.

Here the number of retransmissions will be 10. And a mobile node will make only the static node as a parent node which will resolve the loops to some extent.

VIII. Simulation Results

Simulation Setup:

Simulation parameters are same as presented previously except here we will use Random Waypoint Mobility Model so that protocol is more reliable for realistic environment[16] [18] [19]. In order to prove the efficiency of the proposed algorithm simulations were run with two different number of static nodes. For simulation purpose 100 nodes are deployed randomly in a rectangular region of 250×250 meters. These nodes are identical in terms of resources and energy. Based on the proposed scheme a small number of nodes are static while the remaining all nodes are kept mobile.

The nodes move in the network region using Random Waypoint Mobility model. The sink node is located at (0, 0). The static nodes are distributed using grid topology in order to cover the entire network region while the mobile nodes are distributed uniformly. The simulation runs in two different scenario: one with 9 static nodes and second with 12 static nodes.

However in original CTP all the nodes are kept mobile except the sink node. The minimum and maximum speed for the mobile node is kept as 2 and 5 respectively. In order cover more area transmission range of static node is 30m while for mobile node is 10m. The transmit output power for static node is 3dBm while for mobile nodes is 0dBm. The simulation rounds are run for different simulation time period and each configuration, hence the results are aggregated.

IX. Results & Analysis:

Based on the proposed scheme the results are emphasized more on data delivery ratio and control overhead.

As shown in the Fig. 8 Data Delivery Ratio (DDR) for Enhanced CTP with 9 and 12 static nodes is compared with original CTP. The DDR ratio is been averaged for different simulation time period.

The DDR is 54.10% for CTP original with the same configurations. While DDR based on the proposed scheme with 9 static nodes is 75.51%. When the number of static nodes increases to 12 nodes, DDR also increases to 79.59% as shown in the Fig. 8.

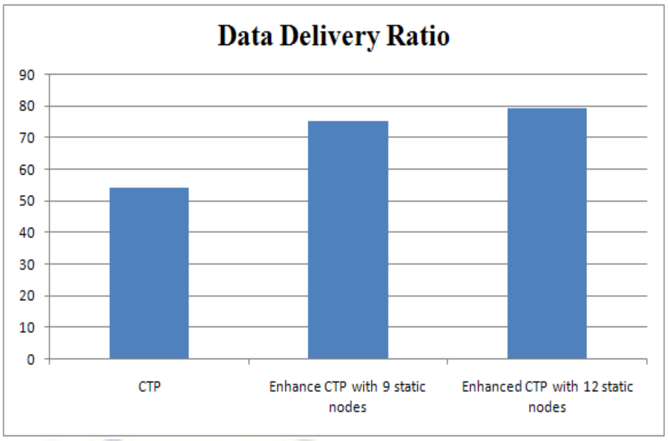

Fig. 8. Data Delivery Ratio

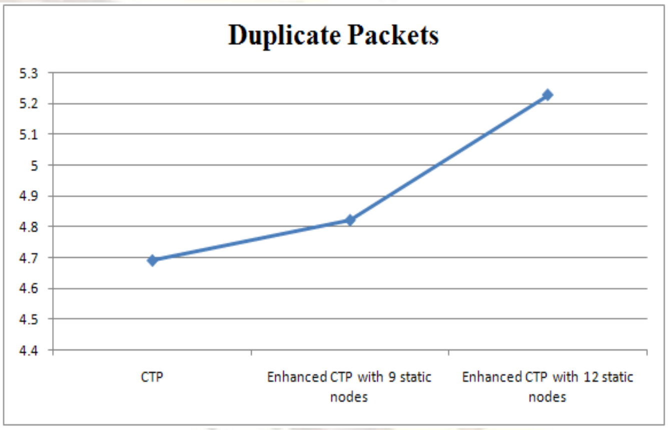

Fig. 9. Duplicate Packets

The number of Duplicate packets sent for original CTP and enhanced CTP is as shown in the Fig. 9. As shown in the figure Duplicates are higher in the Enhanced CTP as compared to the original CTP. The reason for the increased duplicates is due to the situation in which packet is delivered to the static node, but as no acknowledgement is received the same packet is forwarded again. With the increased number of static node this redundancy is also increased. However, the reliability achieved by adding few static nodes at the cost of control overhead is acceptable when the static nodes have higher battery life which also increases the network lifetime.

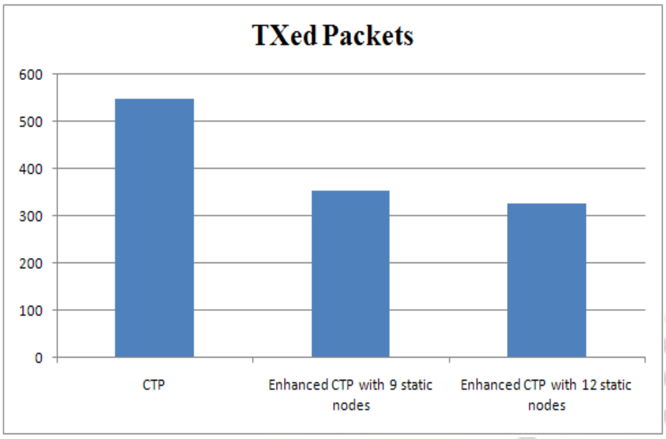

Fig. 10. Transmitted Packets

Fig. 10 shows the number of packets transmitted during the simulation time. It is observed that the transmitted packet ratio decreases in the Enhanced CTP as compared to original CTP.

Packets transmitted for Enhanced CTP with 12 static nodes are less than packets transmitted for Enhanced CTP with 9 static nodes. It shows that control overhead is decreased in the proposed scheme.

As shown in the Fig. 11 the Beacon packets transmitted and received for original CTP are more as compared to Enhanced CTP which increase the control overhead. While in Enhanced CTP with 9 and 12 static nodes, the beacon packets transmitted and received are comparatively less. It shows that control overhead is reduced in the proposed scheme.

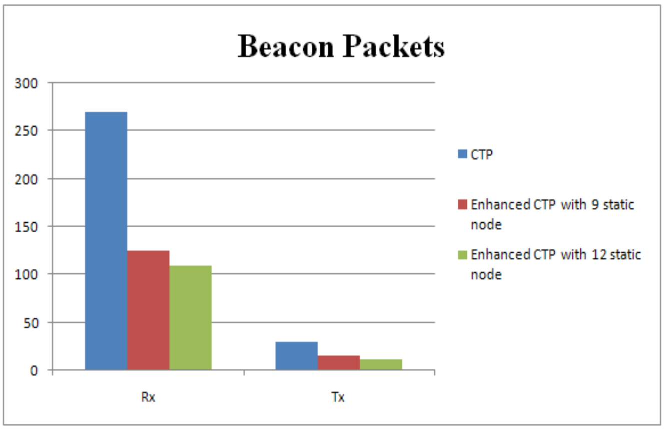

Fig. 11. Beacon Packets

X. Conclusion

From the simulation results we can conclude that the performance CTP is degraded in mobile environment. Due to the mobility topology is been changed frequently which results in frequent tree regeneration. Control overhead increases when the nodes are mobile.

It can be concluded from the results that the path metric estimation makes CTP unsuitable for mobile environment. Based on this analysis an algorithm is presented to increase the efficiency in mobile environment. Some changes were performed in the algorithm in order to increase the performance in mobile scenario. Here few nodes are kept static with increased transmission range. The static nodes are deployed in such a way that most of the network region is covered by them. The link estimation is still done but now a mobile node will select a nearby static node first based on the ETX value. A static node thereafter can transmit data to the mobile node with lowest ETX value.

From the Simulation Results we can conclude that the described algorithm is more efficient than the original CTP in mobile environment. The Data Delivery Ratio is increased in the mobile environment. The control overhead is also reduced over here.

Acknowledgment

We would like to express our gratitude towards our parents for their kind co-operation and encouragement which help us in completion of the work done so far.

References

JOURNAL PAPERS:

[1] Silvia Santini and Ugo Colesanti, "*The Collection Tree Protocol for the Castalia Wireless Sensor Networks SimulatorBased On Its Implementation For The*," Technical Report Nr. 729, Department of Computer Science ETH, Zurich, June 2011.

[2] Javad Rezazadeh, Marjan Moradi, Abdul Samad Ismail, "*Mobile Wireless Sensor Networks Overview*", IJCCN International Journal of Computer Communications and Networks, Volume 2, Issue 1, February 2012.

[3] S. R. Sawant, R. R. Mudholkar, V.C.Patil Rajashree.V.Biradar, "*Multihop Routing In Self-Organizing Wireless Sensor*," IJCSI International Journal of Computer Science, vol.8, no. 1, 2011

[4] Peter PECHO, Petr HAN´ACˇEK, Jan NAGY, "*Simulation and Evaluation of CTP and Secure-CTP Protocols*", Radio Engineering, Vol 19, April 2010.

[5] K. Srinivasan, M. Kazandjieva, S. Agarwal, and P. Levis,"*The beta-factor: Measuring wireless link burstiness*", In Proceedings of the 6th ACM Conference on Embedded Networked Sensor Systems (SenSys), 2008.

[6] Athanassios Boulis, "*Castalia's User Manual*", NICTA, March 2011.

[7] J.,Filali, F.,Bonnet, C Harri, "*Mobility models for vehicular ad hoc networks: a survey and taxonomy*," Communications Surveys & Tutorials, IEEE, vol. 11, pp. 19-41, 2009.

[8] I.F. Akyildiz , W. Su , Y. Sankarasubramaniam , E. Cayirci, "*Wireless sensor networks: a Survey, Computer Networks*", The International Journal of Computer and telecommunications Networking, v.38 n.4, p.393-422, 15 March 2002.

[9] M. Chu, H. Haussecker, and F. Zhao, "*Scalable Information-Driven Sensor Querying and Routing for ad hoc Heterogeneous Sensor Networks*", The International Journal of High Performance Computing Applications, Vol. 16, No. 3, August 2002.

[10] W. Su, Y. Sankarasubramaniam, and E. Cayirci I. Akyildiz, "A survey on Sensor Networks," *IEEE communications Magazine*, vol. 40, 2002.

WEBSITES:

[11] Athanassios Boulis et al. Castalia: A Simulator for Wireless Sensor Networks.[Online] http://castalia.npc.nicta.com.au/

[12] OMNeT++ User Manual (Version 3.2): [Online] www.omnetpp.org/doc/omnetpp33/manual/usman.html

THESIS:

[13] Piergiuseppe Di Marco, "*Protocol Design and Implementation for Wireless Sensor Networks*", Masters' Degree Project, Stockholm, Sweden April 2008.

[14] Mahmood Ali and Sai Kumar Ravula, " *Real-Time Support and Energy Efficiency in Wireless Sensor Networks*", Master Thesis in Computer System Engineering, School of Information Science, Computer and Electrical Engineering, Halmstad University, Technical report, IDE0805, January 2008

[15] Ays¸eg¨ul T¨uys¨uz Erman, *"Multi-Sink Mobile Wireless Sensor Networks: Dissemination Protocols, Design and Evaluation*", Degree of doctor, University of Twente, September 2011

[16] Dixit Sharma, "Evaluating and improving collection tree protocol in mobile wireless sensor network", M.A.Sc. thesis, UOIT, Canada, 2011.

CONFERENCES:

[17] S. Singhal, A.K. Gankotiya, S. Agarwal, and T. Verma, "*An investigation of wireless sensor network: A distributed approach in smart environment*", In Advanced Computing Communication Technologies (ACCT), 2012 Second International Conference on, pages 522 – 529, Jan. 2012.

[18] Dixit Sharma, Ramiro Liscano, and Shahram Shah Heydari, "Collector Tree Protocol (CTP) performance in mobile Wireless Sensor Networks." IEEE Canadian Conference on Electrical and Computer Engineering (CCECE), Niagara Falls, Canada, 2011.

[19] Dixit Sharma, Ramiro Liscano, and Shahram Shah Heydari , "Enhancing Collection Tree Protocol for Mobile Wireless Sensor Networks", submitted to the 4th International Conference on Emerging Ubiquitous Systems and Pervasive Networks, Niagara Falls, Canada, 2013.

BOOKS:

[20] E Holger Karl and Andreas Willig. *Protocols and Architectures for Wireless Sensor Networks*. John Wiley & Sons, Ltd, Chichester, UK, April 2005. ISBN 9780470095126.doi: 10.1002/0470095121. [Online] URL: http://doi.wiley.com/10.1002/0470095121.