Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Performance evaluation of CCM and TSCP routing protocols within/without data fusing in WSNs

IOP Conf. Series: Journal of Physics: Conf. Series **1032** (2018) 012054 doi:10.1088/1742-6596/1032/1/012054

Performance evaluation of CCM and TSCP routing protocols within/without data fusing in WSNs

Haydar Abdulameer Marhoon[1], M. Mahmuddin[2], Shahrudin Awang Nor[2], Mohsin Hasan Hussein[1] and Ahmed Sileh Gifal[1]

[1]College of Sciences, Computer Department, University of Kerbala, Iraq
[2]InterNetWorks Research Lab, School of Computing, College of Arts and Sciences Universiti Utara Malaysia, UUM Sintok, Kedah, Malaysia

haydar@uokerbala.edu.iq

Abstract. Wireless Sensor Network (WSN) is a large number of small sensor devices that can connect each other wirelessly. WSNs applications are rapidly growing in last decades, furthermore, in WSN research, energy is one of the important issues that must consider when designing a new protocol. Due to the fact, almost all of nodes' energy deplete in the communication part, and the data fusing directly impact the performance of routing protocol. This paper studies the impact of data fusing for chain based routing protocols. In this study, ns-3 simulator used to evaluate Chain-Cluster Mixed (CCM) and Two Stage Chain Protocol (TSCP) routing protocols with deterministic nodes deployment. The experiments show that TSCP overcomes CCM in network lifetime when data fusing applied while CCM overcomes TSCP in the same metric with non-fusing of data for First Node Die (FND), 10%, 25%, 50% and Last node (LND). Furthermore, CCM is still playing a good behavior in delay for both approaches. The main conclusion for this paper is non-fusing of data must be applied when design new routing protocol to study all the packets traffic behaviors in the path from source to destination.
Keywords: Chain based, Routing Protocols, CCM, TSCP, Data fusion, WSN

1. Introduction

WSNs have become a challenging area for researchers in different perspectives. Its applications are growing in the last few decades in different areas [1] such as habitat monitoring, industrial company, health and medical, military issues, disasters prediction and management, security, agriculture and others [2]–[4]. Sensors network makes connections between computational, physical and human environment, and data collected from environment by sensors and delivered to the base station using node networking and this process in every round. In general, WSN consists of large number of small devices called Sensor Node (SN). All sensor nodes have the ability of sensing data, processing and communicating wirelessly with each other, and these sensor nodes have limitations in memory, power resources, bandwidth, and computational capability [1]. Second one is a super node which has unlimited resources call Base Station (BS) that works as a sink.

Basic sensor node architecture consists of four units [5]: the first one is sensing unit that is responsible for sensing the outside environment according to its capability for example temperatures, humidity, light and so on. The second unit is for processing, memory, and all computing and processing operations, it is also different according to nodes types and it has almost limited ability. Third is communication unit that makes the necessary connections and network. Furthermore, this unit has the largest power consumption among all node units. Finally, power (battery) unit is working as energy supplier for all units in sensor node. Figure 1 shows the basic architecture for sensor node in WSNs.

Many factors can directly affect the performance of WSN. These factors are including the ways sensors nodes will be deployment in the sensing area (randomly or deterministic deployment), the routing protocols that will be used to create a suitable directions to the base station and is the sensors will use data fusing or not that's depend on when the data collecting and the type of data.

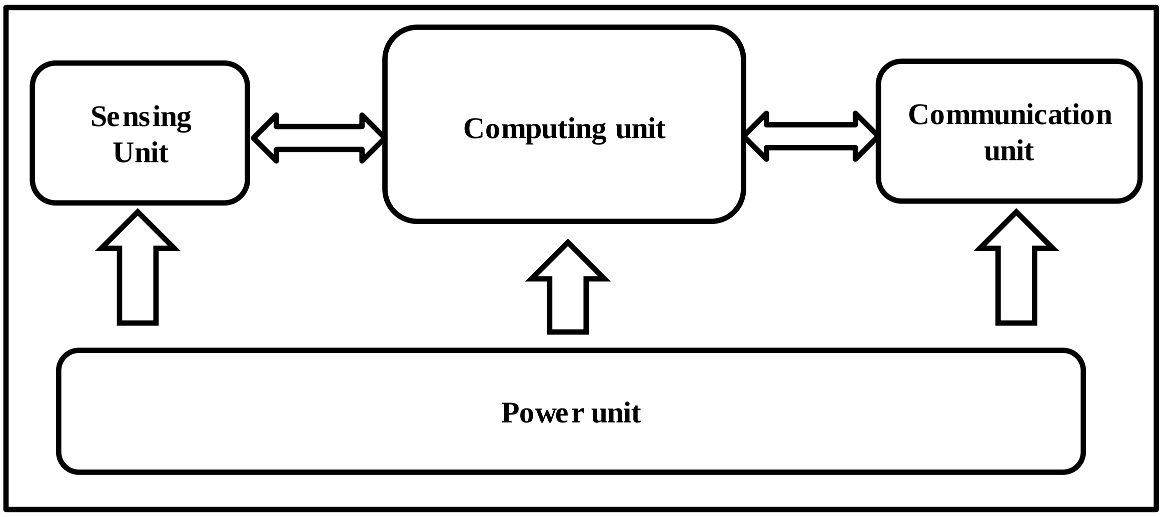

Figure 1. Basic Architecture for Sensor Node in WSNs (Adopted From [6])

This paper studies the differences between data fusing and non-fusing in chain based routing protocol and it will use CCM [7] and TSCP [8] as examples to investigate their behavior in both approaches.

2. Sensors Deployment in WSNS

The sensors deployment method can affect the performance of whole WSNs. Choosing the good sensors deployment can reduce the node redundant, minimize the network overall cost, prolong the network lifetime and reduce the complexity of data fusing and routing [5], [9]–[11]. So, the main issue in sensors deployment is to use effective way in order to increase the coverage area, to provide the efficient nodes connection and energy saving.

Damuut and Gu [12] classified node deployment into two main types first is deterministic and second is non-deterministic nodes placement. A node placement scheme depends on the following three things:

1. Application area: deterministic is more suitable for healthcare, scientific measurements, domestic appliance and it is common in surveillance applications for example in agricultural area [12]. However, non-deterministic is preferred in military, forest fire detection and disasters application.
2. Type of sensor: In some cases nodes deployment depends on nodes characteristics such as weight, size or materiel.
3. Cost: nodes cost, maintenance cost, installation cost is important parameters in choosing deterministic or non-deterministic deployment.

Figure 2 shows the number of nodes that deployed in Deterministic and Random ways in the sensing area:

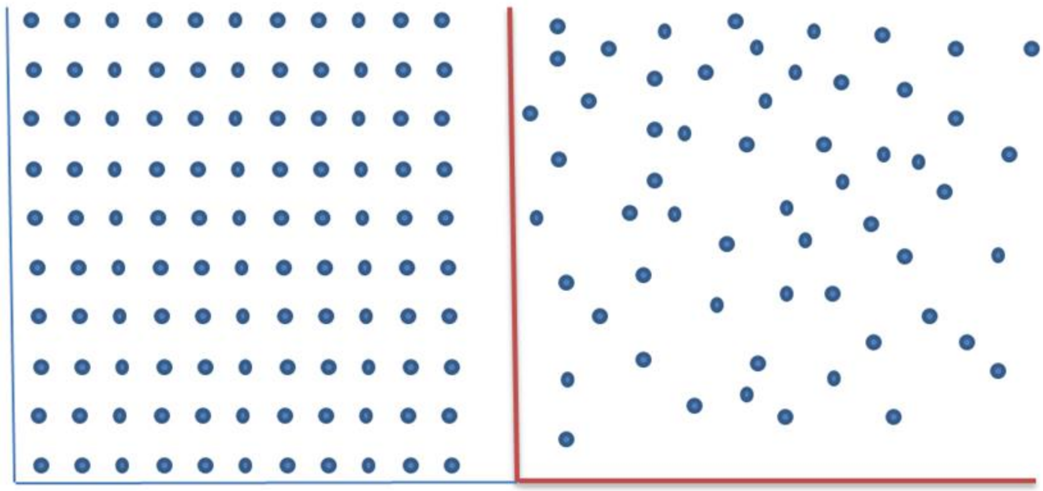

Figure 2. Deterministic and Random Nodes Deployment

Deterministic strategy is the best placement of nodes in the sensing area and sensor location which will not change during network lifetime [9]. Moreover, Deterministic Sensor Placement scheme (DSP) [13] is a common scheme in nodes deployment to meet some specific performance objectives after good planning for nodes position [14]. The main advantages of DSP are its utilization for sensors devices, controllable network topology, more efficient routing protocols and coverage performance. However, time for consuming installation is still the main drawback in deterministic nodes deployment.

Furthermore, random deployment (or non-DSP) strategy is used in some area that have time-sensitive application due to its quick deployment and self-organization which has very important drawback in network lifetime in terms of the number of nodes death in every round [12].

3. WSNS Applications

The sensors technologies are widely used in many applications related with particular life of the human nowadays. Figure 3 illustrate some of the most important applications of WSNs in different area and domain [15][16][17]. The specific characteristics of application are required specific type of sensors, routing protocol, and deployment strategies (deterministically or randomly). The environments and energy consumption is important parameters to choosing the proper types of sensor for applications, due to the energy is serious problem for the network designer [16].

4. Data Fusing in WSN

Sensors node may generate redundant data, so it applies a data aggregation to prevent the duplication for the same data and decreasing the number of packet transmissions. The aggregated (fusing) data is a combination of packets that are collected from different nodes and put together to decrease the number of packet and its size [18]. Many functions use for fusing data such as maxima, minima, duplicate suppression and average. Data fusing techniques are very efficient to increase the lifetime in WSN, especially when multi-hop routing applied in that network. However, non-fusing must be considered when designing a new routing protocol to study the real behavior of packet transmitting from source to destination.

In this paper, the way of data fusing applied based on data fusion technique. Data fusion is the processes of combination n packets with size k and the result will be one packet of size k instead of one packet of size nk [19].

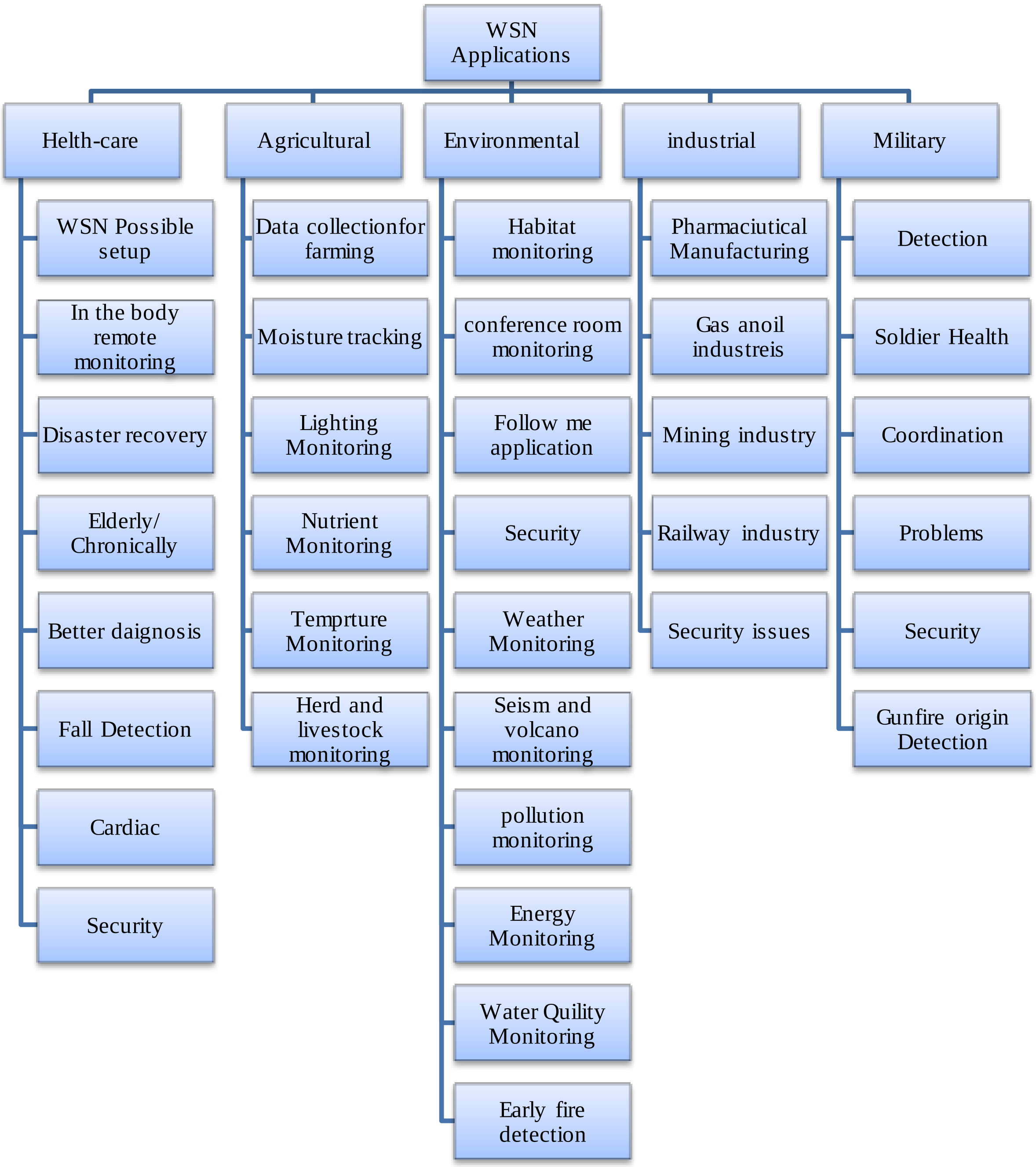

Figure 3. WSNS Applications in Different Area

The main goal of data fusion is to decrease the number of the packets that transmitted in the network. If the same data transmitted without data fusing, the size and the number of the packet will be increase gradually and energy consumption will dramatically increase. Depend on the data fusing energy consumption that proposed in [20], the cost of energy for data aggregation is 5nJ/bit/message. Whereas, the equation to calculate the amount of energy for each packet is below:

$$\boldsymbol{E}_{fusion}\,(\boldsymbol{k}) = \boldsymbol{E}_{fn} * k \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where, $\boldsymbol{E}_{fusion}$ means the energy consumption for data fusion for k-bit per packet, Efn is the energy consumption for fusing 1-bit message. Moreover, for experimental comprehensive study this paper will exams the impact of data fusing for the routing protocols and focusing on TSCP and CCM chain based routing protocols.

5. Chain Based Routing Protocols in WSNS

The chain base routing protocol approach considered as the best among all other energy efficient routing protocols in WSNs [8][21]. Furthermore, deterministic nodes deployment can reduce the redundant node, minimize the network overall cost, prolong the network lifetime, reduce the complexity of data fusing and routing and make the network topology more controllable [9][12][5].

Therefore, many protocols used in chain-based routing approach with deterministic sensors deployment in WSN to achieve efficient energy consumption during the network lifetime [22]. CCM and TSCP will be discussing in details in the next sections in terms of their phases.

5.1. Chain Construction

In CCM protocol all sensors nodes are evenly deploy in the sensing area, so two dimensional assigned name can be taken to every nodes as its id like S(i,j) where i refers to the number of row and j is the number of column. Then, the chain will be constructed among all nodes in the same row (for S(i,1), S(i,2), S(i,3), ….), this means the number of row is equal to the number of chains in this protocol. From every chain, one node is responsible for being a chain head, and the chain head makes a cluster (one hop cluster) and the main head sends its data to the base station. Figure 5 shows the chain and the cluster built by CCM.

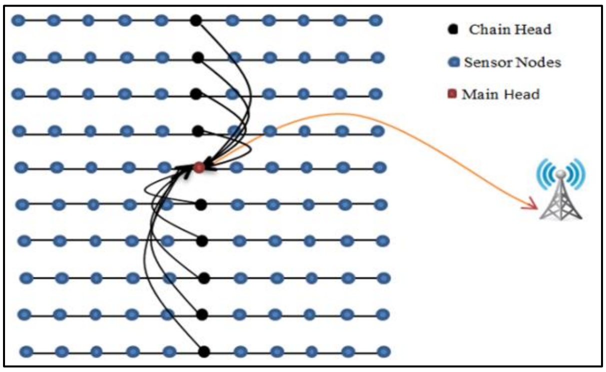

Figure 4. Chain and Cluster Formation in CCM

CCM can reduce the power consumption in intra connection by playing chain concept every node will tune its power radio to hear two neighbors only. However, it conserves more energy when cluster approach is applied in inter connection and when nodes heads are far away from each other. On the other hand, TSCP as in Figure 6 takes advantage from CCM when it built in tow stage chain. The chain is horizontal and as if CCM has intra connection where every node in the same row will connect to two neighbors only (that means the number of the horizontal chain is equal to the number of rows in the network).

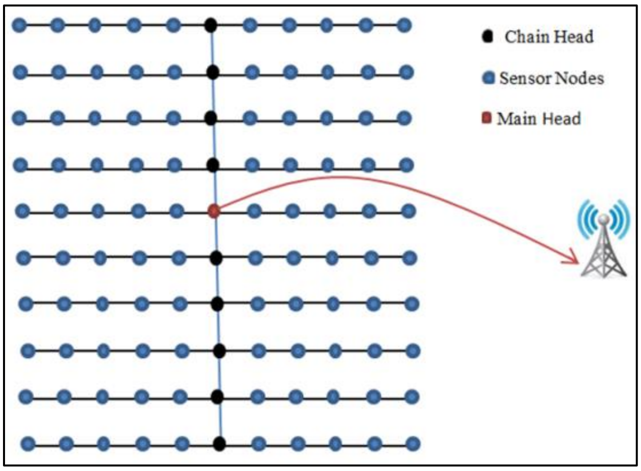

Figure 5. Chains Constructed by TSCP Protocol

TSCP successfully reduce energy dissipation and made energy balances sensor nodes during sequential moving of inter chain (vertical chain for chain heads). However, author does not clearly mentioned about dies nodes, and how the network will deal with these issues. TSCP protocol applies a new method in the network when nodes share almost of their energy in vertical chain. Chain construction will depend on nodes that have maximum energy to build the main chain and this method really can affect the network performance when vertical nodes are far away from each other.

5.2. Chain Head and Main Head Selection

Typically, there are two ways to select CH in WSNs depending on the parameters that are used: deterministic way which depends on fix parameters and adaptive way that depends on variable parameters like remaining energy (weight-based method) [23]. CCM has assigned chain head in each row (horizontal chains) sequentially for every round (node 1 will be chain head in first round and node 2 will be chain head in the second round and so on). Moreover, CCM will choose the main head based on residual energy in chains heads, for which nodes has the highest energy. It will then be the main head and it will be responsible for delivering all network data to the.

Therefore, choosing sequential method to select chain head can reduce overhead on the network and minimize energy dissipation in computation processing. However, ignoring the nodes remaining energy, and this will make some nodes that have few energies to become the chain heads and these nodes will drain their energy quickly where, if these nodes die, the network will lose chains data in this round. As such, chain head is responsible for sending all chain data to the main head. Moreover, CCM uses residual energy only when selecting the main head has critical cases. Specially, when the main head is far away from the base station, while, some chains heads have little bit less energy but with very good position according to base station. In these cases, this node (main node) will spend its energy to deliver all network data to the sink and maybe die earlier than others. In TSCP, chains heads will be selected by sequential way like CCM, for round 1, first node in the chain will be assigned as the chain head in every row (horizontal chains), so a vertical chain heads will construct vertical chain and the chain head that has maximum residual energy will be the main head in this round.

As mention above, the sequential method has critical drawbacks when ignoring the remaining energy to select chain head, but TSCP will put another way to select CH when the network nodes drains their energy by choosing the chain head depending on the maximum energy for all nodes in the same row. However, this way will add more drawbacks to TSCP because vertical chain will affected by long chain if chains heads are far from each other and this will make nodes spend their energy more quickly than the sequential way. Moreover, for main head in TSCP, it is not enough to consider energy only for selection. Distance from base station is very important factor for the main head selection because distance d2 will increase by long distance and d2 is the main factor in energy consumption.

Additionally, single main node in all of these protocols caused a bottleneck problem, since, one node only plays as gateway for network. This research takes bottleneck problem from power consumption perspective not from congestion side because all network's data must be delivered to the base station by this node (main node) as result main node will drain its energy very quickly.

5.3. Next hop Selection and Data Aggregation

Intra-connections in CCM, and TSCP are the same, connection starts from the first node in the row, this node will select the next hop by distance only and this connection will be repeated sequentially (for example node S(i,1) will be connect to its neighbor S(i,2) and so on). This type of choosing does not have flexibility for any change in the network so, if any node dies for example node S(i,2) they will make S(i,1) connection to S(i,3) directly though S(i+1,1) is nearer than other. Greedy algorithm uses distance only to select next hop connection and this considered inefficient method because some nodes are not suitable to be in the chain due to their low energy.

CCM uses chain head to send message sent by to every end node in the chain in order to inform them to start sending data to their neighbors. This neighbor will fuse receiving data with its data then forward it to the next hop. Simple way used in TSCP to send nodes data. Every node senses data and fuses it with received data then transmits it to the next hop. TSCP way is simple but it ignores data collisions without any arrangement for data sending.

6. Radio Model for Energy Consumption

This research apply the First Order Radio Model as energy model, which is the same radio model discussed in [24][20][25]. In this model, the energy that is needed for running transmitting or receiving circuit is E_{elec} = 50 nJ/bit and the energy that is required by the transmitting amplifier is E_{amp}= 100 pJ/bit/m2. So, Equation 2 is used to transmit k-bit from any node to other with d distance between them and Equation 3 is to receive k-bit in any node.

For Transmitting k-bit

$$E_{TX}(k,d) = E_{TX-elec(k)} + E_{TX-amp}(k,d)$$

$$\boldsymbol{E_{TX}\ (k,d) = E_{elec} * k + E_{amp} * k * d^2} \text{ .... } \mathbf{(2)}$$

For Receive k-bit

$$E_{Rx}(k) = E_{Rx-elec}(k)$$

$$\boldsymbol{E_{Rx}(k) = E_{elec} * k} \text{ .... } \mathbf{(3)}$$

where E_{TX} is energy for transmitting, E_{elec} is energy to run transmitting circuit for 1 bit, E_{amp} is energy required for amplifier for 1 bit for m2, k is number of bit and E_{Rx} is energy required to receive k bits. Figure 7 shows the basic elements of the first order radio model [26].

7. Experimental Evaluation

Network simulation 3.22 version (ns-3.22) [27] is used to make a comparison between CCM and TSCP in tow case, first when data fusing approach is applied to aggregate the data from all sensor nodes, second when data transferring without data fusing for all nodes. ns-3 is select for two reasons, first because it is realistic, open source network simulation, and second because it became very rising in WSN research area.

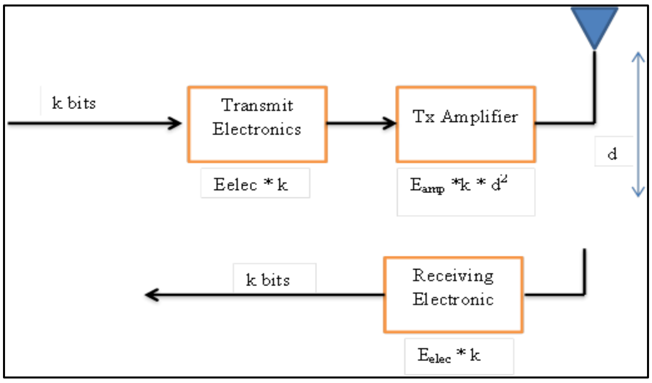

Figure 6. First Order Radio Model

7.1. Performance Evaluation with Data Fusing

In this approach, every node will receive one packet from its neighbour then fuse this data with its own data and the output will be only one packet with same size. Therefore, CCM and TSCP chain based routing protocols compared by using ns-3.22 simulator with the following simulation settings:

Table 1. Simulation Settings

Parameters	Setting
Simulator	ns3.22
Number of nodes	90
Initial energy	0.25 J
Energy model	First order radio model
Base Station	Static and single BS
Packet length	1024
Dist. between Nodes	10 meter
Sensing area	100 m X 100
Routing Protocol	CCM, CCBRP
Energy cons. For data fusing	5nJ/bit
Node deployment	Deterministic with Static Mobility Model

To study the impact of data fusion in WSN there are two important metrics need to calculate, first is the network lifetime and second is the End-to-End delay.

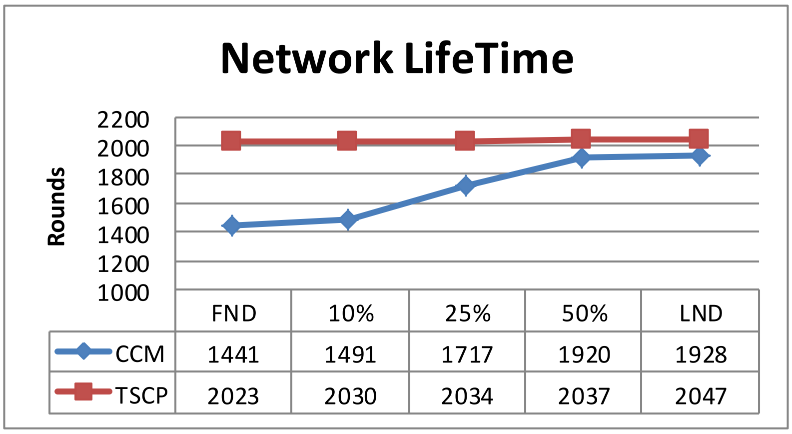

Figure 7. Network Lifetime for CCM and TSCP with Data Fusing

The Figure 8 illustrates the difference of network life time between CCM and TSCP, where y axis refer to number of round and x axis for percentage of nodes die. This is easy to show that TSCP outperform CCM in the first node die, 10%, 25%, 50% and last node die. This is very important to calculate the robustness of the routing protocol; furthermore, how it is keep the sensors node live as long as possible.

As mentioned above, CHs in TSCP are connected to each other as a chain, so it is keep the energy that spend by the long distance (distance consider very important factor). While all CHs in CCM connected to the main head directly, it will spend more energy and reduce the network lifetime for all nodes.

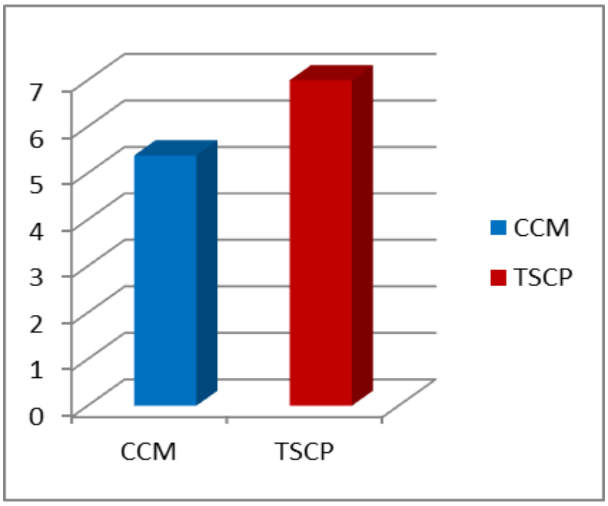

Figure 8. Average End-to-End Delay for CCM and TSCP with Data Fusing.

End-to-End delay is an important metric in WSN, which measure the speed of data delivery from the source to the destination. From Figure 9, TSCP has more delay than CCM this is coming from the internal behavior of second mechanism of TSCP. Data redundant will occur when every CH transmitting its data to the nearest CH until reach the base station. While CCM is outperforming TSCP in delay metric coming from cluster base behavior of CHs connection.

7.2. Performance Evaluation without Data Fusing

Data fusion is an active technique for reducing the data that delivering or transferring among network nodes but it is also has a lot of disappoint that is need to discus and study like delay for data fusing, network behavior, energy consideration, fusing algorithm and weight method that used if non data fusing is applied. So in this section paper will exam same routing protocols CCM and TSCP (chain based routing protocols) but without data fusing to study different with the previous results. Weight method will be used in both protocols that's mean every node responsible to transmit what receive with its own data. Figure 10 shows the network lifetime for CCM and TSCP routing protocols with same simulation setting except the initial energy that will be 2j for more comprehensive studying. For non-data fusing approach CCM outperform TSCP in the all metrics in the network lifetime section. This is coming from reducing the amount of data redundancy in CHs connection mechanism (cluster based).

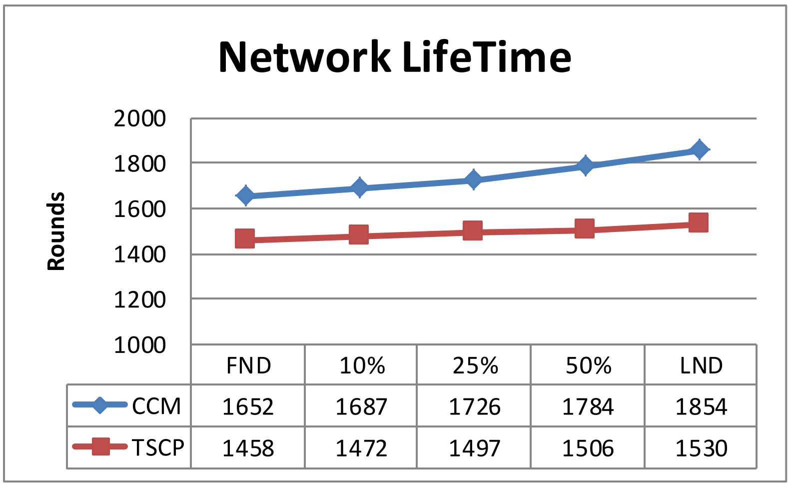

Figure 9. Network Lifetime for CCM and TSCP without Data Fusing.

Furthermore, End-to-End delay is important metric needs to exam with data fusion approach to calculate the behavior of both protocols from delay perspective, because of delay consider the main problem in the all chain based routing protocols in WSN.

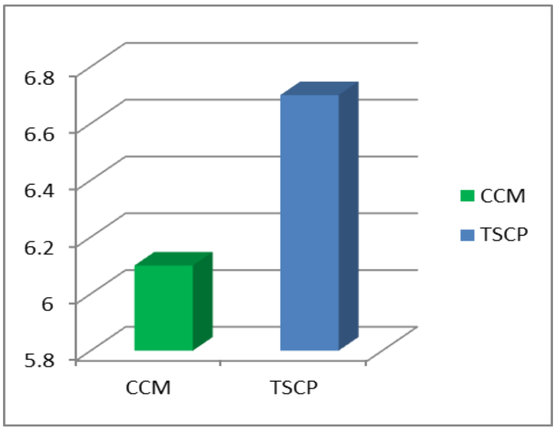

Figure 10. Average End-to-End Delay for CCM and TSCP without Data Fusing.

Figure 11 shows that CCM still outperforms TSCP in delay metric, because of reducing the length of CHs by using single hop connection between them and must be mention here that the delay causing by data fusing very difficult to calculate in WSN due to it is consider as processing delay.

8. Discussion and Conclusion

Energy consumption is main consideration in all WSN research special in routing protocols designing because of the almost of node's energy deplete in data transmitting between nodes. In this paper CCM overcome TSCP in delay metric in both approach. This is coming from behavior of the second phase in CCM when CHs connect each other using cluster form to reduce the delay cause by long link. This result lead the researcher to mixing chain based to reduce power consumption with cluster based to reduce the delay. While TSCP overcome CCM in the network lifetime when data fusing approach applied because of few number of packets traveling with smallest distance between CHs while, CCM play good performance with non-fusing approach because of the intermediate CHs are not responsible to deliver the previous data and this will reduce the power consumption for CHs and prolong the network lifetime. From all these point, there is not big difference by data fusing or non-fusing when the researcher (protocol designer) interested with delay metric and anything related. While it must consider if designing related with extend the network lifetime.

For future work, designing new routing protocol must take the advantage of both chain and cluster based and makes fair balancing to reduce the power consumption, extend network lifetime and reduce delay. In addition, non-fusing for data recommended applying for make real packets traffic.

9. References

[1] X. Liu, “A survey on clustering routing protocols in wireless sensor networks.,” Sensors (Basel)., vol. 12, no. 8, pp. 11113–53, Jan. 2012.

[2] M. Eslaminejad and S. A. Razak, “Fundamental lifetime mechanisms in routing protocols for wireless sensor networks: a survey and open issues.,” Sensors (Basel)., vol. 12, no. 10, pp. 13508–44, Jan. 2012.

[3] Y.-K. Chiang, N.-C. Wang, and C.-H. Hsieh, “A cycle-based data aggregation scheme for grid-based wireless sensor networks.,” Sensors (Basel)., vol. 14, no. 5, pp. 8447–64, Jan. 2014.

[4] H. A. Marhoon, M. Massudi, and A. N. Shahrudin, “CHAIN-BASED ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS: A SURVEY,” ARPN J. Eng. Appl. Sci., vol. 10, no. 3, 2015.

[5] W. Y. Poe and J. B. Schmitt, “Node Deployment in Large Wireless Sensor Networks : Coverage , Energy Consumption , and Worst-Case Delay,” in AINTEC’09 Conference Proceding, Bangkok, Thailand, 2009.

[6] S. Rana and A. Aggarwal, “Study and Comparison of Chain Based Protocol to Enhance Energy Utilization in Wireless Sensor Network,” Int. J. Comput. Sci. Mob. Comput., vol. 3, no. 8, pp. 11–17, 2014.

[7] F. Tang, I. You, S. Guo, M. Guo, and Y. Ma, “A chain-cluster based routing algorithm for wireless sensor networks,” J. Intell. Manuf., vol. 23, no. 4, pp. 1305–1313, May 2010.

[8] H. Kareem, S. J. Hashim, S. Suberamaniam, and A. Sali, “Energy Efficient Two Stage Chain Routing Protocol (TSCP) For Wireless Sensor Networks,” J. Theor. Appl. Inf. Technol., vol. 59, no. 2, pp. 442–450, 2014.

[9] H. Zhang and C. Liu, “A Review on Node Deployment of Wireless Sensor Network,” IJCSI Int. J. Comput. Sci., vol. 9, no. 6, pp. 378–383, 2012.

[10] G. Huang, D. Chen, and X. Liu, “A Node Deployment Strategy for Blindness Avoiding in Wireless Sensor Networks,” IEEE Commun. Lett., vol. 19, no. 6, pp. 1005–1008, 2015.

[11] X. Liu, “A Deployment Strategy for Multiple Types of Requirements in Wireless Sensor Networks,” IEEE Trans. Cybern., vol. 45, no. 10, pp. 2364–2376, 2015.

[12] L. P. Damuut, “A Survey of Deterministic Vs . Non-Deterministic Node Placement Schemes in WSNs,” in The Sixth International Conference on Sensor Technologies and Applications, 2012, no. c, pp. 154–158.

[13] S. Meguerdichian, F. Koushanfar, G. Qu, and M. Potkonjak, “Exposure in wireless Ad-Hoc sensor networks,” Proc. 7th Annu. Int. Conf. Mob. Comput. Netw. - MobiCom ’01, pp. 139–150, 2001.

[14] J. Li, L. L. H. Andrew, C. H. Foh, M. Zukerman, and H.-H. Chen, “Connectivity, coverage and placement in wireless sensor networks.,” Sensors (Basel)., vol. 9, no. 10, pp. 7664–93, Jan. 2009.

[15] M. Kuorilehto, M. Kohvakka, J. Suhonen, H. Panu, H. Marko, and T. D. H, Ultra-Low Energy Wireless Sensor Networks in Practice Theory, Realization and Deployment. U.S.A: John Wiley &Sons, Ltd, 2007.

[16] S. Khan, A.-S. K. Pathan, and N. A. Alrajeh, Wireless Sensor Networks, Current Status and Future Trends. Taylor & Francis Press, 2013.

[17] B. Krishnamachari, Networking Wireless Sensors: Sleep-oriented MAC – Efficient Routing Data-centric Concepts – Congestion Control. New York: cambridge university press, 2005.

[18] K. Akkaya, K. Akkaya, M. Younis, and M. Younis, “A survey on routing protocols for wireless

sensor networks," Ad Hoc Networks, vol. 3, pp. 325–349, 2005.

[19] H. Ö. Tan and I. Körpeoğlu, "Power efficient data gathering and aggregation in wireless sensor networks," ACM SIGMOD Rec., vol. 32, no. 4, p. 66, Dec. 2003.

[20] C. S. Lindsey, Stephanie Raghavendra, "PEGASIS : Power-Efficient GAthering in Sensor Information Systems '," in Aerospace conference proceedings IEEE, 2002, pp. 3–1125.

[21] K. S. Ahn, D. G. Kim, B. S. Sim, H. Y. Youn, and O. Song, "Balanced Chain-Based Routing Protocol (BCBRP) for Energy Efficient Wireless Sensor Networks," 2011 IEEE Ninth Int. Symp. Parallel Distrib. Process. with Appl. Work., pp. 227–231, May 2011.

[22] H. A. Marhoon, M. Mahmuddin, and S. A. Nor, "DCBRP: A Deterministic Chain-Based Routing Protocol for Wireless Sensor Networks," Springerplus, vol. 5, no. 2035, pp. 1–21, 2016.

[23] C. Wei, J. Yang, and Y. Gao, "Cluster-based routing protocols in wireless sensor networks: A survey," Proc. 2011 Int. Conf. Comput. Sci. Netw. Technol., pp. 1659–1663, Dec. 2011.

[24] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," in Proceedings of the 33rd Hawaii International Conference on System Sciences, 2000, vol. 0, no. c, pp. 1–10.

[25] S. SUMITHRA and A. A. VICTOIRE, "An Energy Efficient Linear Chain-Based Clustering Routing Protocol For Wireless Sensor Networks," Theor. Appl. Inf. Technol., vol. 63, no. 3, 2014.

[26] W. B. Heinzelman, "Application-Speci c Protocol Architectures for Wireless Networks," Cornell, 2000.

[27] "Network Simulator 3," 2015. [Online]. Available: https://www.nsnam.org/. [Accessed: 28-Feb-2015].