Energy-Efficient Clock Synchronization Technique For IoT Nework

Ernest Ezema
Dept. of Comm. Technology and Networks, Universiti Putra Malaysia
Serdang, Malaysia
ernestezema@gmail.com

Azizol Abdullah
Dept. of Comm. Technology and Networks, Universiti Putra Malaysia
Serdang, Malaysia
azizol@upm.edu.my

Nor Fazlida MD Sani
Dept. of Computer Science, Universiti Putra Malaysia
Serdang, Malaysia
fazlida@upm.edu.my

***Abstract*— Energy saving, and clock synchronization is critical to Internet of Things (IoT). In recent time, several energy efficient clock synchronization techniques have been proposed by different authors with the aim of finding solution to energy saving in IoT network. However, some of this technique (R-sync) utilizes a lot of energy with unsynchronized nodes, thereby making the algorithm not suitable for IoT Network. The technique obtains higher precision without considering the energy utilization. Unnecessary expenditure of energy leads to collision of sensor nodes. In our research, we proposed a Network Node ID (NN-I) technique for energy efficiency by applying the network node ID to avoid collision, achieve clock synchronization and energy saving. MATLAB was used for the simulation and the evaluation parameters for the simulation were the number of broadcast messages, the level of energy consumption and collision count. All experiment in the base work where used. The result of our research indicates a more improved clock synchronization and energy saving for IoT Network against the existing technique.**

Keywords— Internet of Things (IoT), Distributed System, Wireless Communication, Computer Networks

I. INTRODUCTION

The Internet advancement in software and telecommunication services which further help in connecting the objects with other potentially capable objects for providing the accomplishment of various services is provided within the IoT. The idea or service to be provided can be of a small computer with a microchip present in it for functional and operation purposes.Wireless Sensor Network (WSN) are known to be the key factor for IoT Model [2]. The idea behind the network is its ability to sense, process data and initiates wireless communication with large number of nodes. The network is faced with energy and other challenges due to its constrained nature, and it makes its management more challenging than the wired network. Clock synchronization is also an important factor to distributed system. It offers the correct function and swift communication of many computer application. Clock synchronization is seen as a procedure offering a common time for distributed system [3]. Utilizing network node ID (NN-I) to organize sending message between network nodes is considered a smart solution as it uses network node ID sequence to organize sending messages without need for additional protocol to set the order of network node to send messages. The motivation for this research is to propose an energy efficient clock synchronization technique that can reduce the energy consumption in IoT network.

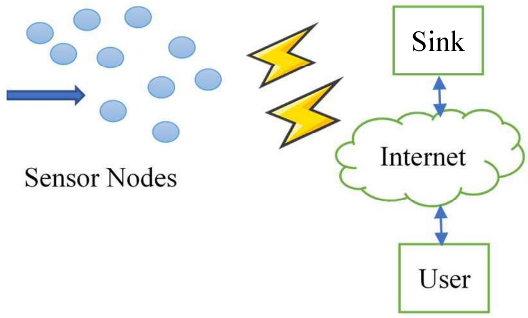

Figure 1: Wireless Sensor Network (WSN)

II. RELATED WORK

Serious research and contributions are being made; ideas are suggested by researchers on how clocks can be synchronized efficiently in order to get a better system performance in IoT. Some of these related contributions are highlighted. Although, most of the contributions have their limitations as they have suggested future work and enhancements which forms the basis of this research. To deal with issues of unsynchronized nodes, and to provide a robust time synchronization scheme for IoT and IIoT, [10] proposed R-Sync which uses a pulling timer to pull isolated nodes into synchronized network. After their experiment conducted using simulation tool NS-2, the result shows that their approach make all nodes get synchronized in terms of accuracy and energy consumption compared with TPSN as proposed by [8] , GPA and STETS algorithm [5]. However, R-Sync algorithm fails to reduce the routing overhead of the network.

There are few methods which can be used to get accurate clock synchronization, namely the Network Time Protocol (NTP); In NTP with the use of Global Positioning System (GPS) a proper synchronized time can be attained. The biggest advantages of using NTP system are that it provides high level accuracy and reliability in terms of clock synchronization. Another method is the Precision Time Control (PTP); PTP is a protocol which is used to synchronize a clock throughout a computer network. On a local area network, it can achieve time and clock accuracy in sub-microsecond range which makes it a good match for measurement and control systems. It is basically designed for applications which cannot afford a GPS tracker at each node [8].

Another researcher [6] proposed a clock synchronization algorithm which is based on the non-coherent timing detection. The coherent timing detectors work on the Rayleigh fading channel technique for the clock synchronization in the IoT. The Rayleigh fading channel technique is very light weight due to which complexity of the system reduced to greater extent. The performance of the proposed technique was analysed in terms of Mean Square Errors (MSE) and it had been analysed that it performs batter than Non-Data Aided (NDA) Coherent technique for clock synchronization. However, another researcher [4] proposed a clock synchronization technique for the Internet of things. It is being analysed that IoT is the highly dynamic network to which time synchronization is the major problem in the network. The optimal solution to this type of problem is to reconfigure the devices for serving different applications. The proposed algorithm for clock synchronization is based on the re-configuring devices based on the reference's clocks. In the proposed technique three modules are used which are application interface, time reference unit and synchronization unit. The application unit maintains communication between low level and high-level modules. The time reference unit gains the access of the local clocks and synchronization unit will adjust the clocks of the device according to application. The performance of proposed scheme was tested in terms of accuracy in comparison to existing techniques.

In [7] argued that there is a need to minimize the energy used in the network and improvement in the synchronization of the sensor's nodes. Due to the weak synchronization of the sensor network clocks, packet loss may occur within the network. This further might result in minimizing the lifetime of the network. This leads the need to enhance the working of the TDMA protocol as TDMA protocol is used to assign the time to various sensor nodes for efficient working of sensor nodes. In this paper, authors use NS2 simulation tool which involve the presence of finite number of sensor nodes and LEACH protocol is used for executing clustering and choosing cluster heads. In this paper authors proposed a Time-lay technique so that Radio Frequency Identification protocol can be improved, and sensor nodes can be synchronized with the help of base station. As per the simulation results achieved the proposed scheme performs well in terms of various parameters.

TABLE 1: ANALYSIS AND TAXONOMY OF RELATED WORKS

Author/Year	Method	Strength	Weakness
[4]	Introduced a mathematical model for a hidden node collision	The analysis of the effect of hidden nodes and collision probability	Does not define other parameters or methods hidden nodes that can cause collision could be prevented.
[1]	Introduced a new linear approximation model for the reduction of the complexity in nonlinear analytical model	The model computes conditional collision probability	Communication between nodes are restricted when the probability is not met
[10]	It presented Spanning Tree-based Energy-efficient Time Synchronization (STETS)	It maintained high accuracy and reduced communication overhead	Energy saving in (STETS) is still very high
[7]	Proposed a hierarchical network design and a model for energy efficiency	The model performs effectively in complex IoT	It does not support constrained IoT devices and WSNs
[9]	Proposed R-sync Algorithm. The author used a pulling timer to pull isolated nodes into synchronized network	Achieved a satisfactory level of accuracy with little consideration to energy consumption	Does not support energy efficient clock synchronization scheme for IoT
[8]	Proposed a lightweight client, and a packet exchange protocol (SPot) for clock synchronization	It reduces various noise level to minimal and achieved a high accuracy of clock synchronization	It fails to support large numbers of clients efficiently
[5]	Proposed a Hy-Top energy aware clustering communication protocol	Uses a probability model to select cluster heads based on level	Focused mainly on the routing overhead

Wireless Sensor Network has no central controller, due to which energy consumption is the major issue. By using bully algorithm, greater probability of becoming Cluster Head is given to node with higher energy for better distribution of energy and more reliable message transmission. In this paper, author had used the diffusion-based technique to synchronize cluster head clock. As per the simulation results achieved energy consumption has been reduced in terms of energy, packet loss and delay. It is also discussed that for large scale Internet of Things, the security of time synchronization is a critical and challenging issue. The malicious sensor nodes could decrease the accuracy of the whole network by broadcasting fake timestamp messages. In this paper, authors proposed a Secure Time Synchronization model for large scale IoT. Then this Secure Time Synchronization Protocol (STSP) was evaluated and compared with the previous protocols (TSPN) and (STETS) using NS2 simulator tool. As per the simulation results achieved proposed protocol is effective to prevent attack from malicious nodes. In summary, for effective performance and efficiency in IoT network, energy should be reduced more to provide more adequate and need services in IoT.

III. PROPOSED WORK

The proposed algorithm in this research, is designed with emphasis to providing high-performance. The algorithm is aimed at decreasing energy consumption in IoT clock synchronization. In this stage, an algorithm is designed for the efficient clock synchronization in IoT. The blueprint is defined to implement the proposed approach. When the approach is designed with the pseudo code and flowchart the development process will be started. The process of design will be the iterative process until the approach will be designed according to research questions. In the last stage, the algorithm which is proposed so far is implemented in MATLAB. The proposed technique from the base station take initial step for the clock synchronization. The base station floods the control messages in the network and when sensor nodes receive control message it will adjust its clocks according to the clock of base station. The proposed scheme is implemented and compared with the previous work. The parameters metrics are decided for the comparison like time and nodes.

Network Node ID (NN-I) Algorithm: In this algorithm, it utilizes the network node ID (NN-I) to organize sending message between network nodes and we consider it a smart solution as it uses network node ID sequence to organize sending messages without need for additional protocol to set the order of network node to send messages. Using this approach, it ensures that it reduces collision with ensures that clocks are synchronized, and energy is saved.

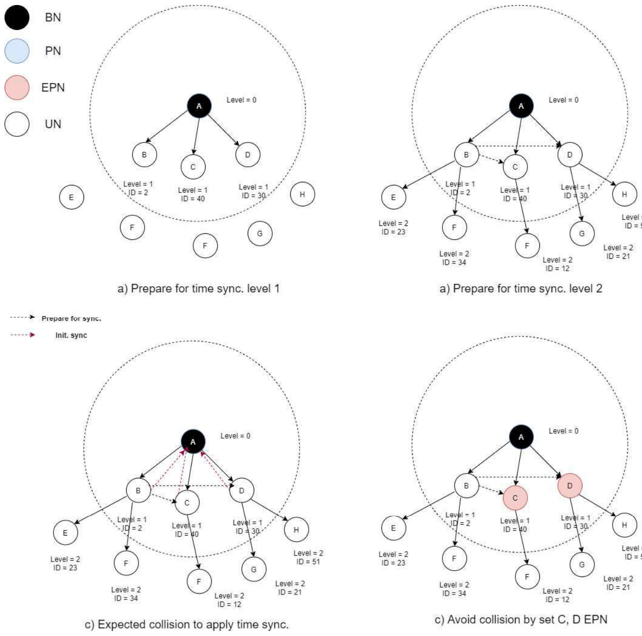

Figure 2: NN-I process stages

In Figure 2a, the first state of time synchronization is done by assigning relationship between root node and level 1 nodes. After that all level 1 nodes try to collect it children by broadcast message to all neighbour node which contains also the nodes in level 1 as in Figure 2b, dashed arrow shows the messages transfer from node B to C, D which is in the same level. As seen in the previous work Figure 2c, the collection can be done in initial time synchronization stage where all nodes try to synchronize with its parent node and only one node can synchronize with the parent using SRP protocol and the other will synchronize using RRP protocol but collision may happen because all nodes try to synchronize with parent node randomly and that can lead to collision. In Figure 2d, we proposed the prevention of collision by letting all node in the same level listen to each other and delegate one node only with lower node ID to use SRP and the other nodes with high node ID uses RRP.

A. Reducing Collision with NN-I algorithm

In R-sync, there are three nodes state as seen in Figure 2 The system can change node from one state to another based on a protocol messages and algorithms to synchronize time. During the process of changing from one state to another, there is tendency for collision because one node will try to represent a group of nodes. R-sync has a protocol with two way to synchronize time between nodes first one by SRP or RRP, in the first SRP protocol all BN children node try to synchronize with parent BN node to become BN node and when a node success to become BN it block children to be BN when other nodes receive notification from parent BN for acceptance for one node to be BN node. The other child nodes in this case become passive node PN and waiting for synchronization between parent BN and child BN to synchronize their time using RRP protocol.

TABLE 2: COLLISION REDUCTION RESULT

Nodes	R-Sync	NN-I
50	2	2
100	5	4
150	17	14
200	40	33
250	54	43
300	77	65
350	80	71
400	96	83
450	110	92

In our research, we proposed modified algorithm based on network node ID to prevent any collision can occurs due to race of children nodes to be BN node. R-sync algorithm proposed "Preparation for Time Synchronization", all node send message to declare its ID and parent ID to all other nodes. Then all nodes try to be BN node by synchronize with parent BN node and this may lead to collision. We can select only max ID or min ID BN children nodes to be the upcoming BN nodes in the next level for children nodes as all children nodes receive a message from this node with its ID and can compare its ID with its ID to decide to leave it as representor for this level as BN or not.

B. Pseudo code for NN-I Algorithm

From the simulation process described in Figure 1 the NN-I algorithm was written. The pseudo code that was used for the NN-I algorithm is described below. The pseudo code starts with the deployment of sensor nodes, then it divided them into clusters and the parameters are defined. If all the conditions are met, as specified for all the cluster heads to get selected in each cluster. At the event all conditions are met in the level discovery phase, the synchronization phase exchanges its clock and makes adjustment to determine the result.

Pseudo code for NN-I algorithm (NN-I)

```
Initialization
if isRootNode = True then
        nodeType ←BN
        broadcast < 0xFFFF; ID; SetT; Null;1;1;0 >
end if
Upon receiving < DestAddr; SrcID;T ype; Prnt ID; RTS; STS; Level >
if Type = SetT and PT is idle then
        set up timer PT
        myLevel ← Level +1
broadcast < 0xFFFF; ID; SetT; Null;-1;-1;myLevel >
if Type = SetT and PT is not idle and myLevel = Level and myParent ← Parent then
        if ID < myID then
                nodeType ←PN
        end if
end if
```

IV. RESULTS AND DISCUSSIONS

In Figure 4.1 the consumption level of proposed algorithm reduced to 0.015 compared to the R-sync algorithm. R-sync is implemented to determine the level of energy consumption for the clock synchronization in IoT against NN-I algorithm. The scenario and the processes are explained. The sensor nodes sense information and transmit it to base station over the wireless channels. The scheme is applied in the network which gives access to the sensor nodes to the wireless channels. Due to the decentralized nature of the IoT, collision may occur when messages are broadcasted in the network. R-sync algorithm allows for large amount of information to be fetched from the server which tense to consume more energy and causes collision. The analysis of our result showed that the NN-I algorithm reduced energy consumption and increase efficiency by using the network ID to reduce collision in the network and prioritize the levels of the sensor nodes during resources sharing.

A. NN-I Energy Saving by Avoiding Collision

The objective of this research is to the enhance energy

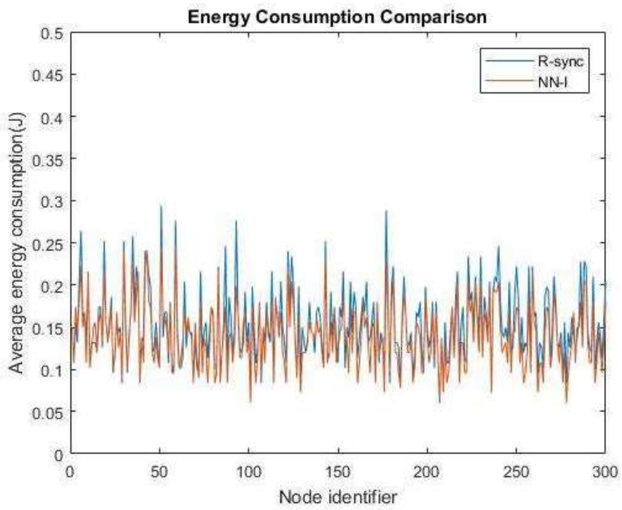

Figure 3: Energy Consumption Comparison

Figure IV: NN-I Energy Saving

efficiency and provide better performance of the network when the clock is adequately synchronized. To achieve this, we compared the result of the previous algorithm which had higher energy consumption rate.

Our results in Figure 4. shows a maximum reduction in energy consumption rate by utilizing network nodes to avoid collision. In node 50, the energy reduced to 0.005 the progression was experimented until node 450 which shows a reduction of 0.015 against R-sync algorithm which had 0.017 as their final energy reduction rate. The result of this simulation further suggests an efficient energy algorithm with clock adequate synchronization.

V. CONCLUSION

A good performance of the network determines its live span and overall workings. The principle objective of this work is to propose an algorithm that will enhance the routing overhead of the network and reduce energy consumption for clock synchronization of nodes in IoT network. R-sync and NN-I techniques where analyzed, both techniques have their own pros and cons. In this research work, we re-implemented and enhanced the R-sync technique for clock synchronization. In the improved technique we used network node ID to reduce collision thereby enhances energy saving in the network. NN-I algorithm is implemented using MATLAB and results are validated in terms of broadcast messages, energy consumption and time error. From the results, we can see that the NN-I technique has efficient energy saving for IoT.

VI. FUTURE WORKS AND RECOMMENDATION

Following are the various areas that can be explored and future possibilities to further improve the performance of clock synchronization in IoT networks. The IoT system generally requires a reduced energy for it to perform very well in its deployed facilities. NN-I algorithm can be further compared with the other algorithms with intentions to further reduce energy consumption of IoT especially the constrained (class 0) IoT devices. Other ways, techniques and solutions should be considered. It is challenging to secure data communication in resource constrained IoT devices because of its limited resources available to support security technologies. Class-0 IoT devices, has a resource threshold less than 100kb ROM and/or less than 10Kb RAM. The NN-I scheme can be further improved to ensure efficiency in the network. More enhancement to reduce collision using network node ID approach is needed. As all nodes in the network almost knows the nodes IDs and status of the spanning tree, we can utilize the information to give slots for each node to start sending new message on time and prevent any collision that may occur between two network nodes that start sending messages the same time.

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