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An analysis of software-defined routing approach for wireless sensor networks☆

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ABSTRACT

In emerging wireless sensor applications, sensor nodes are equipped with low battery and limited capacity when transmitting the sensed data to the sink.To prolong the lifetime of sensor networks, the energy consumption has to be reduced and the bandwidth channel utilization has to be improved. To accomplish these requirements, we have proposed a new scheme as software based multi-flow in wireless sensor network. This scheme is developed based on the Software Defined Network (SDN) and allocates separated channels for data plane and control plane. It also generates inbuilt software module in every sensor nodeto increase the speed of the network. The proposed scheme is used to maintain the topology and also manages the limited battery power usage. Experimental results demonstrate the performance of the proposed software based multi flow in terms of indispensible network parameters including throughput, delay and energy consumption.

1. Introduction

Today Wireless Sensor Network (WSN)s are employed in various applications ranging from battlefields to medical diagnosis applications. These networks are basically ad hoc networks, possessing self-configuring capabilities, equipped with tiny and limited battery and memory resources. A wireless sensor network is used to monitor the environment and then the condition of the environment will be forwarded to the sink with the help of sensor nodes. In general, sensor nodes of wireless sensor networks are deployed in a distributed manner. The major issues in the wireless sensor network are its limited battery capacity and its demand for high degree of energy consumption. Due to its emerging energy needs, a sensor node may completely get drained off at some period and at this junction, it is said to a dead node. While many sensor nodes die in a network, this may produce a high dropping rate and degrade the network performance and efficiency. The major applications of the wireless sensor networks include environmental monitoring, process monitoring, object tracking and disaster recovery. The major purpose of the sensor network is to monitor the events or objects based on the requirements of these applications and confined to the nature of applications.

The sensor node in the sensor network have interface cable, battery, radio, microcontroller, software module and analog circuit. Interface cable is used to connect any two sensor nodes and the battery will assign energy for the sensor nodes. This battery is of less weight and low capacity. To maintain the minimum battery level, microprocessor is required to change the node to sleep state after every data transmission and change back to active state before every data transmission. Analog

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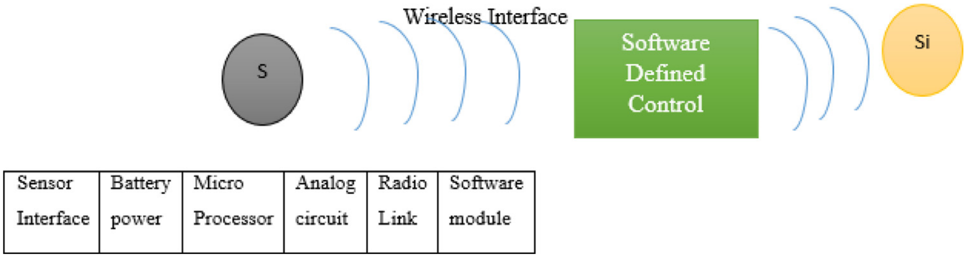

Fig. 1. Components of software controlled sensor network.

circuit design is used to increase the speed of the processor. Software module is in-built in each sensor node to make the communication efficient.

Software Defined Network (SDN) is a mechanism used to separate the control plane and data plane in the computer network. This Software Defined Network has open flow process, which is used to forward the data packets and it acts like a switch or router. Open flow is the subset of the Software Defined Network. In the place of a router or a gateway or an access point, a Software Defined Network can be employed to transmit the data with less energy consumption and low cost.

Fig. 1 shows the components of software controlled sensor network. It consists of software defined controls and sensor nodes that are connected via IEEE 802.11 wireless interface to the sink. A sensor node is built of software module blocks. Software Defined Control(SDC) of wireless network is used for replacing the existing gateway, router and access points in the network. Li W et. al [10] presents two different scheduling schemes to reduce the energy consumption in wireless sensor networks. Delay minimization oriented routing protocol is used to reduce the energy consumption in nodes and load balancing oriented routing protocol is used to reduce the energy consumption during the packet transmission. Gao et. al [5] propose a new routing protocol to develop the Quality of Service (QoS) in wireless sensor networks. Energy efficiency is major concern in sensor network that can be handled by using the proper selection of routing protocol and this selection indeed accomplishes the requirements of Quality of Services (QoS) in sensor networks. Ulucinar AR et. al [17] presents the distributed flow radio channel assignment for the multi radio and multi-channel in wireless mesh networks. Due to the random deployment of topology present in mesh network, resilience and link failure arises and these two major issues could be solved by using the distributed flow radio channel assignment scheme.

2. Related work

Our work considers significant classical and modern attempts and triumphs made towards achieving energy efficiency in wireless sensor networks from microscopic and macroscopic perspectives. Jindamaneepon et. al [7] suggests the FPGA based multi-channel, multi-interference scheme for wireless nodes in wireless network. This scheme is used to avoid the interference in multiple channels provided between the source and destination. Prasad Joshi G et. al [12] discusses about an efficient Medium Access Control (MAC) protocol for the wireless sensor networks to make the better channel assignment among the data nodes. The proposed MAC protocol is used to increase the aggregated output and increase the network efficiency. Hao et. al [6] proposes the joint power control and multi-channel assignment model which is used to reduce the energy consumption as well as the network interference. Farooq et. al [4] explains about the available bandwidth metric for the ad hoc networks. The proposed available bandwidth metric in this work is suitable for both multi-path channel and short hop count scheme, which in turn improves the network performance. Cho et. al [3] presents the camera surveillance system which consists of a master/slave architecture. Slave system stores the image and video that are received and forwarded by the master system. Lee et. al [11] discusses about the camera sensor network in which each node having the ability to visualize the environment. This camera sensor network is used to increase the network performance and to decrease the delay and routing overhead. Vadlamani et. al [18] presents the jamming attacks for military application to disrupt the terrorists' communication. In summary, the survey indicates the need for an integrated system of technologies to improve the wireless sensor networks, especially concerning the tradeoff existing amidst the parameters.

3. Problem formulation

The connected distributed network with software module is given as the input of the problem and the expected output is the wireless sensor network with less energy consumption and low delay. To make the better communication, the data plane and control plane are separated. To increase the speed the network, the software module is defined in the network.

1. The first representation is assigning the sensor node, $Sn = \sum_{i=1}^{n} Sn(i) + Sm$ which states the assigning software module for each sensor node in the wireless sensor network. Where Sn represents sensor node, i is the number of nodes vary from 1, 2, 3.….n. and Sm represents software module. This equation is used to increase the processor speed with the help of software module. Software module is used to connect the open flow subset of the Software Defined Network. Compared to the existing routers, this Software Defined Network will forward the data in a faster manner.

2. Connecting the nodes to the Software Defined Network (SDN) can be done with the following equation as $Sn(Sm) + SDN, \ \forall \ Sn(i) \in Sm$. Only the software module's sensor node can connect to the Software Defined Networks as stated in Eq. 2.

Tree PAN routing scheme (TOMTPR) [9] uses the pilot channels for multi-channel allocation between the pair of source and destination nodes. Distributed Renewable Generation (DRG) [19] technique employs the smart grid technology in the wireless sensor network to avoid the high traffic during multi-channel communication. Routing for video sensor network is applicable for both smart grid technology and vehicle to vehicle communications [8]. This techniques extends the multi-channel bandwidth allocation so that it can reduce the energy consumption and to increase the data rate. Low power mode algorithm, power aware routing strategy and compression techniques [1] are involved to increase the efficiency during the emergency condition which occurs due to the energy consumption. Distributed Wireless Sensor Network(DWSN) architecture uses the clustering technology to maintain the wireless nodes in the network. Correlative function [15] can reduce the energy consumption with the help of uploading the redundant data. Energy Hole Aware Energy Efficient Communication (EHAEC-IF) algorithm with 1-fault tolerance [20] is used to reduce the energy consumption even in high topologic changes with the help of redundant method. Optimized Prioritized Load Balancing approach (OPLB) [16] is used for scalable routing scheme in Wireless Sensor Network. Multi Hop Routing Energy Efficient Routing Scheme (MRER) uses the optimal cluster head [14] to reduce the energy consumption and increase the network lifetime. Routing agent (RA) [13] is used as data aggregation technique to reduce the energy consumption when compared to the use of standard LEACH algorithm. Cross layer design (CLD) is used to reduce the energy consumption [2] in the wireless sensor network which creates a line between the MAC layer and network layer to reduce retransmission. All the above schemes are used to reduce the energy consumption and increase the network efficiency and at the same time, it does not satisfy the full requirements of sensor network.

4. Motivation

A substantial inspirational force of our work is obtained from Connected Low Interference Channel Assignment (CLICA) scheme which is used in the channel instead of colors between the source node and destination node. This scheme assigns two different colors for the channel in which the first color is used for representing the first transmission. The second color is used to represent the second transmission. By differentiating the color, it reduces the channel interference. Alteration of color can be selected for the each transmission that reduces the interference.

Assigning the channel as color will differentiate into two colors. After every transmission, colors will be altered that reduces the channel interference. But the drawback in this technique is only two colors are used which denotes the two channels between the source and destination.

For example, four nodes are considered namely a, b, c and d. 'a' to 'b' selects first color and the 'b' to 'c' selects the second color. Alteration starts in 'c' to 'd' takes first color and 'd' to 'a' takes second color. If 'a' and 'c' wants to transmit the data at the time, 'a' should take the second color to transmit the data. Because between 'a' and 'b' the first color has been chosen, the second color is now selected to transmit the data to 'c'.

5. Software based multi flow algorithm

Software based multi flow algorithm has three different phases based on their steps. First phase represents the process of assigning the routing protocol, second phase is assigning the channel between sensor nodes and sink nodes and third phase is controlling the topology and energy usage. This proposed algorithm is applicable for multi flow, which utilizes the bandwidth effectively and also enforcestopology control. The process of this algorithm is created in the wireless network with the sensor nodes in a distributed manner. The entire sensor network transmits the sensed data to the sink through the base station or server. During that transmission, high traffic may occur which in turn produces high collision. To avoid that, proposed scheme introduces two different channels for control message and data message.

In general, wireless network is used to transmit RTS (Request-to-Send), CTS (Clear-to-Send), DATA and ACK (Acknowledgement) among the wireless nodes. RTS and CTS messages travel on control plane whereas DATA and ACK messages use the data plane. Here, one channel is especially dedicated for the control messages and another channel is completely assigned for data messages. Initially, control messages get the information about the sensor node. If the channel medium gets a CTS message, the free sensor node is allowed to transmit the data and the acknowledgment is produced through the data channel. A sensor node sends the control messages to other sensor node also simultaneously when the data is being transmitted from this node. This can effectively reduce the delay and energy consumption. By using the control plane, topological changes are intimated immediately to the other sensor nodes. This mechanism reduces the drop rate as well as energy consumption. Avoidance of unwanted transmission conspicuously reduces the energy consumption and delay.

Our proposed scheme is used to maintain the topology, to increase the data rate and to decrease the energy consumption. The term 'software based' denotes the Software Defined Network. Software Defined Network creates the Multi flow routing protocol. This routing generates two different routing paths for two different channels as used in the proposed algorithm. These two different channels are programmatically configured for each sensor node. That is possible through Multi flow routing protocol. This protocol creates the multiple flows for the multiple data which travels between the sensor node and the sink node. By using this routing protocol, the creation of network is initiated. This creates the network in a distributed architecture in which all the nodes are deployed in a random manner. If any node leaves or a new node enters the network, that will be intimated to other nodes using the control plane path. To know the status of the sensor node, the control plane path is used. To transmit the data alone, it uses the data plane path. This can increase the network performance and reduce the delay, drop rate and energy consumption.

5.1. Multi flow routing protocol

This Multi flow routing protocol is created with the help of Software Defined Network. The following set of assumptions is made in this routing protocol:

1. Create the network in a distributed architecture and sensor node deployment happens in a random manner.
2. Consider two different channels for each sensor node, one is assigned for control transmission and another one is assigned for the data transmission.
3. When there is any topological change, neighbor nodes will intimate about the node movement to the remaining nodes in the network.
4. All the sensor nodes are fully connected with two different channels in the name of c-chan and d-chan. 'c-chan' represents the control message transmission between the sensor nodes and 'd-chan' represents the data message transmission among the sensor nodes.

Based on the aforementioned set of rules, multi flow routing protocolis activated. The network architecture is created in a distributed manner.

Theorem 1. *Let connectivity graph is denoted as C and it contains nodes Ň and links Ĺ. If C has an odd cycle and it has 2 link coloring in which both colors are represented in each node at least for two links.*

Proof. Consider the connectivity graph C as nontrivial. If C is eulerian and it has an even cycle that required the property for the edge 2 coloring. Set the degree of the node with the help of Euler tour based on the links.

$$L = \{li|\ i \in Odd\}; \tag{1}$$

$$L = \{li\ |\ i \in even\}; \tag{2}$$

□

Eqs. (1) and (2) are counting the number of links in the network. If the number of links is odd, the theorem has proved. If the number of links is even, it requires the Euler property.

Euler property creates the new connected graph as C*. Also, this graph adds one more node as Ň and it forms the connected graph C* having an odd cycle. That satisfies the above theorem and it makes each node in the network with two edge coloring.

Count the colorings in each node Ň that is denoted as C (Ň). Let the number of edges is denoted as $\pounds = \prod_{i=1}^{K} \acute{L}i$.

Lemma 1. *Suppose X is the vertex for the connectivity graph C. The two distinct colors are represented as 'I' and 'j', such that i is not considered in X and j is considered as atleast twice of X.*

Proof. The number of edges as $\pounds = \prod_{i=1}^{K} \acute{L}i$ and it has an even cycle. Based on the above statement, this can be changed as an even cycle by improving the network in which the edges are denoted as $\pounds * = \prod_{i=1}^{K} \acute{L} * i$.Here, counting the distinct colors are represented as C*(X).

i.e, C*(X)=C(X) +1. □

5.2. Channel allocation

Fig. 2 shows the network architecture for the proposed algorithm. Each node has two different paths namely, data path and control path, colored in blue and red, respectively. All the sensor nodes have separate paths for data transmission and control transmission. This proposed algorithm uses the two edge coloring scheme for data and control transmission. This type of path differentiation remarkably reduces the collision, traffic rate and also energy consumption. This proposed technique achieves this with the help of an efficient, cognitive, energy-aware channel allocation mechanism.

Theorem 2. *The connectivity graph C as reduces the interference bounded in the channel assignment problem and also preserves the energy consumption.*

Proof. As mentioned in Fig. 2, the energy consumption is reduced □

Interference is reduced even in the allocated channel. Considering two separate paths for control messages and data messages, we can view the reduction in the interference. Generally interference occurs due to the collision of data messages and control messages. Separating the path for the data and control messages reduces the interference. Interference is directly proportional to the energy consumption. If the interference reduces, energy consumption will also get reduced.

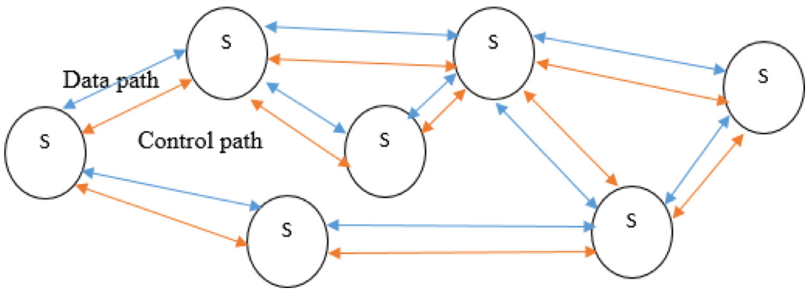

Fig. 2. Channel allocation.

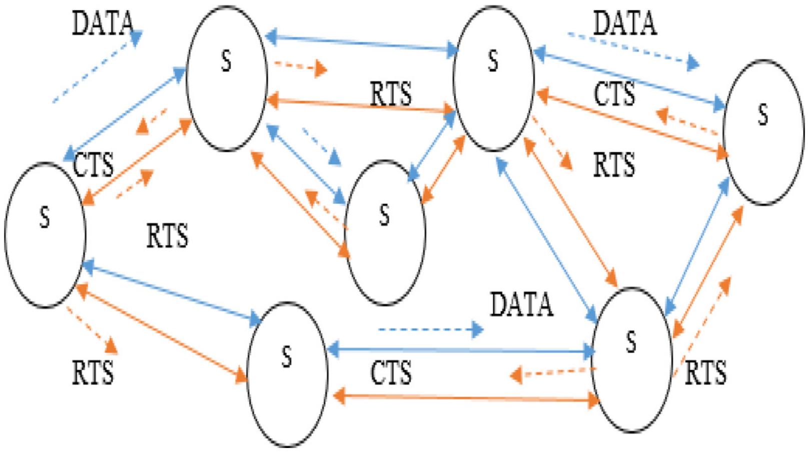

Fig. 3. Multi flow data transmission.

Fig. 3 shows the multi flow data transmission scheme. This scheme can transmit the data in multi direction using the multi path. The proposed algorithm consists of two different paths for the data transmission and control path. While transmitting the data, sensor node will detect the status of the neighbor node using the control path and the control messages. This helps in increasing the delivery rate and throughput. The use of two different channels for data messages and control messages will reduce the collision and hidden terminal problem. The channel allocation allows the allotted channel differentiate the channels for data messages and control messages.

5.3. Topology control

This proposed Software Based Multi- Flow (SBMF) algorithm is used to control the topology. If any neighbor node moves out of range, that neighbor node will intimate about the mobile node to the remaining nodes in the network through the control channel. Let us consider that the sensor node as Sa(Ň) and within the range of neighbor node as Na(Ňi). Where i represents the number of neighbor nodes in the network.

$$Sa\left(\check{N}\right) \in \mathrm{V}_{i=1}^{N} Na\left(\check{N}i\right) \tag{3}$$

Consider that the N = 4, the number of neighbor nodes are considered as 4 for the Sa(Ň). Here, the third neighbor node Na($\check{N}_3$) leaves within that coverage range of the sensor node Sa(Ň).

$$Sa\left(\check{N}\right) \rightarrow \left\{Na\left(\check{N}3\right)\mathbb{C}Lm(Cp)\right\} \rightarrow \left\{Na\left(\check{N}1, \check{N}2, \check{N}4\right)\right\} \tag{4}$$

Eq. (4) states that the sensor node would intimate about the leaved node as Na($\check{N}_3$) to the remaining nodes in the network through the control path. Where Lm denotes the leaving message and Cp denotes the control path.This equation can be used to control the topology changes and also to reduce the issues that can occur due to the topology changes. When the topology changes, it may increase the delay and drop rate. But this proposed Software Based Multi Flow (SBMF) algorithm reduces the delay and drop rate.

Table 1 shows that the topology maintenance in the proposed Software Based Multi Flow (SBMF) algorithm. Here, four sensor nodes as Sa, Sb, *Sc* and Sd are considered. Each sensor node has some limited coverage range; within this coverage range, neighbor nodes are identified and labeled as Na, Nb, Nc and Nd, respectively. If any neighbor node leaves that range, respective sensor node will intimate this to the remaining nodes in the network. This Software Based Multi-Flow (SBMF) algorithm controls the topology changes by allocating the different channels between the sensor nodes.

Table 1
Topology maintenance.

Sensor nodes	Coverage range	Number of neighbor nodes	Leaves that range	Intimation
Sa	Na(1), Na(2), Na(3), Na(4)	4	Na(3)	$Sa(\check{N}) \rightarrow \{Na(\check{N}3)\complement Lm(Cp)\} \rightarrow \{Na(\check{N}1, \check{N}2, \check{N}4)\}$
Sb	Nb(1), Nb(2), Nb(3)	3	Nb(2)	$Sb(\check{N}) \rightarrow \{Nb(\check{N}2)\complement Lm(Cp)\} \rightarrow \{Nb(\check{N}1, \check{N}2)\}$
Sc	Nc(1), Nc(2), Nc(3), Nc(4)	4	Nc(4)	$Sc(\check{N}) \rightarrow \{Nc(\check{N}4)\complement Lm(Cp)\} \rightarrow \{Nc(\check{N}1, \check{N}2, \check{N}3)\}$
Sd	Nd(1), Nd(2)	2	Nd(1)	$Sd(\check{N}) \rightarrow \{Nd(\check{N}1)\complement Lm(Cp)\} \rightarrow \{Nd(\check{N}2)\}$

Source node	Destination Node	Source address	Destination address	Hop count calculation	Distance calculation	Path calculation	Energy consume	Time taken

Fig. 4. Multi flow routing table.

5.4. Software module

Each sensor node has in-built software module to perform the effective communication in software defined network. This software-defined controller will not only act as router but also as an access point. This in-built software module sensor node has the ability to access the multi-flow routing table. This multi-flow routing table has the program for calculating the hop count, distance and suitable path between the source and destination.

5.4.1. Routing table calculation

1. $Hc = COUNT(Sn : Dn)$\\\\ Hop Count Calculation
2. For {i = 0;i ≥ n; i++}
3. If Hc(i + 1) > Hc(i)
4. Assign Hc(i + 1)→Sp(i)
5. Else
6. Repeat if
7. End
8. End
9. $Dc = \sqrt{\{(D(i) - S(i)\}^2 - \{D(j) - S(i)\}^2}$
10. If Dc(i) < Dc(i + 1)
11. Assign Dc(i)→Sp(j)
12. Else
13. Repeat if
14. End
15. End

where, Hc denotes the hop count, Sn denotes source node and Dn denotes destination node. If a condition is used to calculate the path, it has lesser hop count that will be taken as shortest path. That shortest path is assigned for the Sp(i).

Where, Dc denotes the distance calculation. Generally, source node has the coordinates of S(i,j) and destination node has D(i.j). Based on these coordinates, distance calculation can be made. Here shortest path estimation is based on the comparison of the two distance values. That shortest path is denoted as Sp(j).

1. If Sp(i)>Sp(j) \\\\ path calculation
2. Sp(j) used for data transmission
3. Else
4. Sp(i) used for data transmission
5. End
6. Finally, path calculation is based on the comparison of two different paths which are calculated based on the hop count of respective paths among which the shortest path will be chosen for the data transmission.

Fig. 4 shows the multi-flow routing table which has source node, destination node, source address, destination address, hop count calculation, distance calculation, path calculation, time taken and energy consume. This source node skips the steps of hop count and distance calculation and directly moves to the path calculation. The software module can be accessed through multi flow routing table where the time taken and also the energy utilized so far are stored

6. Results and discussions

The performance of the proposed Software Based Multi-Flow algorithm has been analyzed using the Network Simulator version 2.32. The scalability is tested by varying the number of nodes from 100 to 600 within the topography of

Table 2
Comparison of channels.

Parameters	Channel 1	Channel 2
Color	Red	Blue
Path	Control	Data
Messages	RTS (Request to Send), CTS (Clear to Send), Leave Message (Lm)	DATA,ACK,NACK
Representation	Chan_1	Chan_2
Packet size	44 bytes/s	512 bytes/s

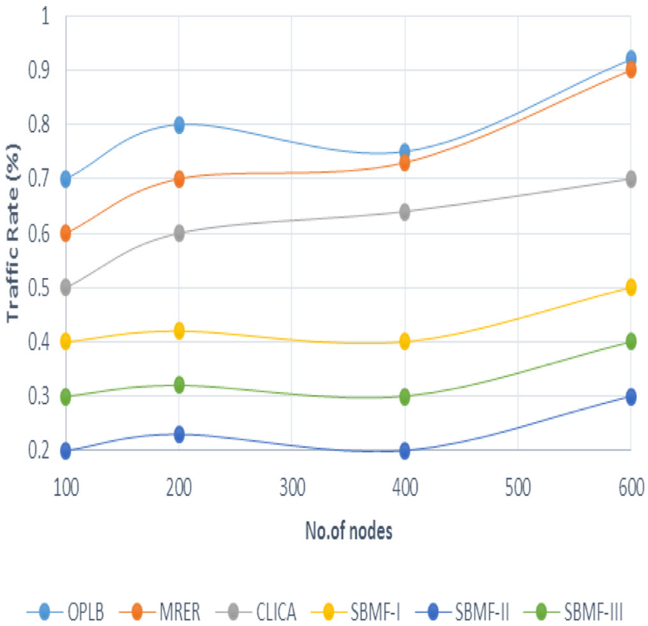

Fig. 5. Traffic rate analysis.

$1000 \times 1000\,m^2$. The channel assigned for each sensor node is Chan_1 and Chan_2 which has red and blue colors, respectively. Initial energy in each sensor is set as 200 J. The allocated channel bandwidth between the each sensor node is 2.5 Mbps. The antenna type is omni-directional antenna, which is used to cover all the directions. The transmission control protocol is used to generate the data packet and the application layer agent as File Transfer Protocol. The data packet size is 1000 bytes per packet and the interval time is 0.01 s. The drop tail queuing mechanism is adopted and the queuing limit is set as 50 packets. The Multi-flow routing protocol generates the routing table for separate channels. Table 2 presents a comparative analysis of these two channels.

This proposed Software Based Multi-Flow Algorithm is used to compare and analyze with the existing algorithm such as Optimized prioritized load balancing approach (OPLB), Multi Hop routing energy efficient routing scheme (MRER) and Connected Low Interference Channel Assignment CLICA scheme. Proposed algorithm has analyzed in three different stages based on various mobility conditions such as 50 m/s, 25 m/s and 5 m/s.

Fig. 5 shows the traffic rate analysis which is defined as the distance covered for each sensor at the unit time. The existing approaches, named, Optimized Prioritized Load Balancing approach (OPLB), Multi-Hop Routing Energy Efficient Routing scheme (MRER) and Connected Low Interference Channel Assignment (CLICA) scheme have high traffic rate due to the heavy load, multi hop relay and channel assignment problem respectively. The proposed Software Based Multi Flow reduces the traffic rate with the help of two separate channels for data and control messages.

Fig. 6 presents the throughput performance analysis which considers the successful delivery ratio of data and control packets within the simulation time. The channel bandwidth is allocated for two different channel is 2.5 Mbps. The proposed Software Based Multi-Flow Algorithm utilizes the bandwidth of 2 Mbps.

The existing techniques, named, Optimized Prioritized Load Balancing Approach (OPLB), Multi-Hop Routing Energy Efficient Routing scheme (MRER) and Connected Low Interference Channel Assignment (CLICA) scheme has lesser throughput compared to the proposed Software Based Multi Flow algorithm. Among them, Optimized Prioritized Load Balancing Approach (OPLB) has inserted the software module sensor node and generates the process. Compared to the simple OPLB, software impact OPLB (S-OPLB) has slighter improvement. Likewise, the same software module has used each sensor node with

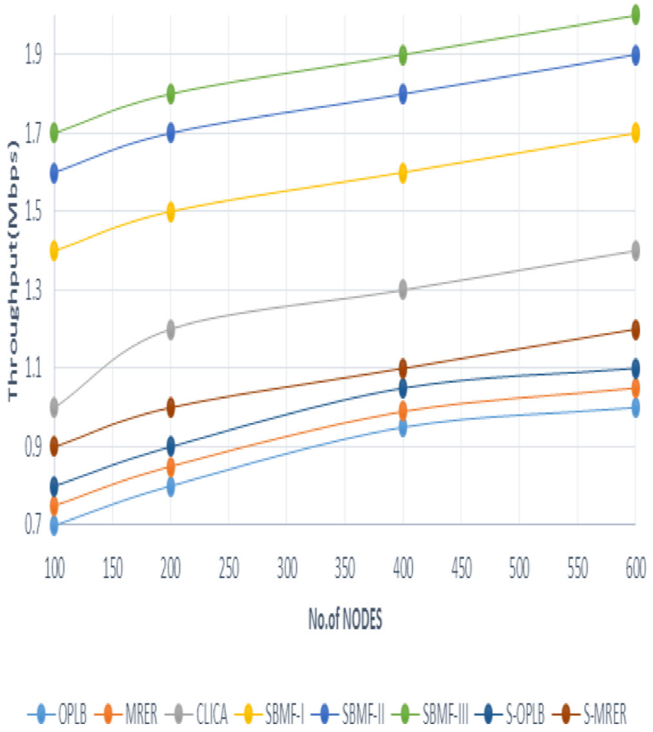

Fig. 6. Throughput analysis.

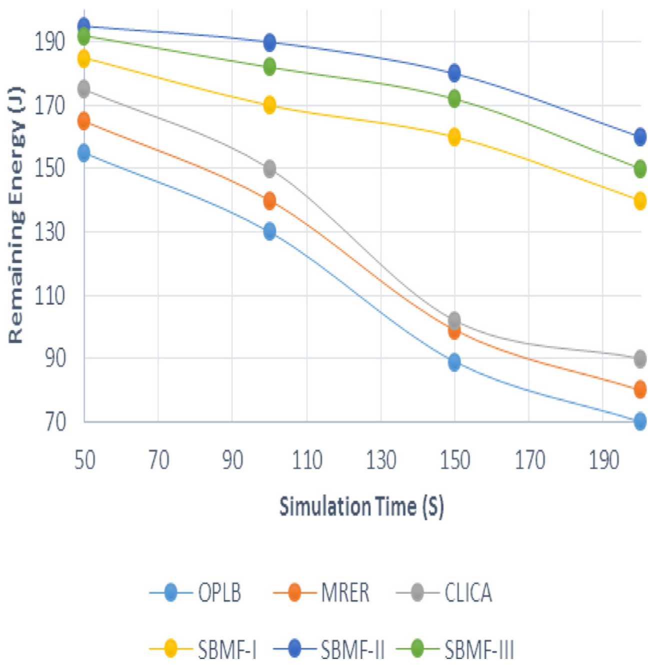

Fig. 7. Residual energy.

the Same Procedure of Multi-Hop Routing Energy Efficient Routing scheme (S-MRER). Compared to normal MRER scheme, Software Impact MRER scheme has slighter improvement.

Fig. 7 shows the residual energy which is defined as the remaining energy in each sensor node during the end of simulation period. It is observed that more energy is consumed in OPLB, CLICA and S-OPLB approaches when compared to the proposed Software Based Multi-Flow Algorithm.

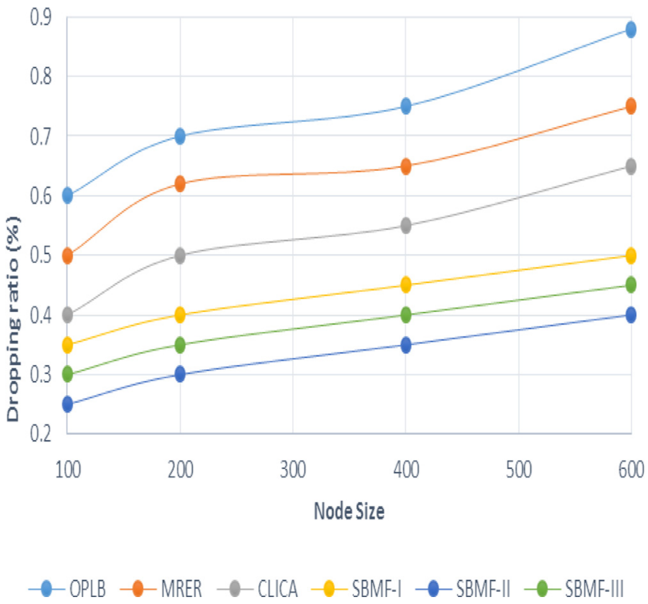

Fig. 8. Drop rate analysis.

Energy efficiency is achieved in the proposed approach owing to its routing efficiency which considerably reduces the communication overhead. Since communication overhead dominates the energy dissipation process, the proposed approach has made attention towards this and obtains encouraging degree of improvement. The energy efficiency gained by the proposed approach helps and signifies prolonged lifetime of wireless sensor networks.

Fig. 8 shows the drop rate analysis which can be defined as the ratio of number of packets successfully received to the difference between the number of packets transmitted and number of packets received. Optimized Prioritized Load Balancing Approach (OPLB) has the highest drop rate of packets due to the rigorous prioritization of data transmission. Multi-Hop Routing Energy Efficient Routing scheme (MRER) shows next higher drop rate due to the multi hop relay between the sensor nodes. Connected Low Interference Channel Assignment (CLICA) scheme shows the next level of drop rate due to the channel assignment complexities. Besides these issues, the proposed Software Based Multi Flow algorithm has low drop rate of 40%–50% compared to the other existing techniques, as it is observed from the results. Topological changes can be intimated sooner in the proposed algorithm that helps substantively in reducing the drop rate.

The delay (time taken to transmit the data from source to destination) characteristics of existing and proposed approaches are depicted in Fig. 9. The proposed Software Based Multi-Flow algorithm has lesser delay due to the separation of data and control paths. The delay is reduced from 0.3 to 0.4 s. But the existing techniques such as Optimized Prioritized Load Balancing approach (OPLB), Multi-Hop Routing Energy Efficient Routing scheme (MRER) and Connected Low Interference Channel Assignment (CLICA) scheme exhibit higher delay compared to the proposed algorithm.

Fig. 10 shows the collision probability by varying the network size from 100 to 600 nodes. In proposed Software Based Multi- Flow algorithm, it has two different channels such as channel 1 for control messages and channel 2 for data messages. Control messages are used to know the status of the channel and also intimate about the topology changes in the network. After knowing the status and intimation, data message will be transmitted through the channel 2. Collision probability is high in channel 1 compared to the channel 2, because channel 1 is used to know the status and also to intimate about the topology changes. The existing techniques such as technique Optimized Prioritized Load Balancing Approach (OPLB), Multi-Hop Routing Energy Efficient Routing Scheme (MRER) and Connected Low Interference Channel Assignment (CLICA) scheme have high collision probability compared to the proposed Software Based Multi Flow algorithm.

In summary, Optimized Prioritized Load Balancing Approach (OPLB) uses the cluster head and it conserves more energy for the frequent cluster head selection processing. Multi Hop Routing Energy Efficient Routing scheme (MRER) suffers from unregulated multi hop relay between the source and destination that increases the delay remarkably. Connected Low Interference Channel Assignment (CLICA) scheme does not promise the requirements owing to the complexity in channel assignment which has been categorized as a NP-hard problem. The demerits of these approaches have been repressed by using the proposed Software Based Multi Flow algorithm with the help of the channel separation for control messages and data messages.

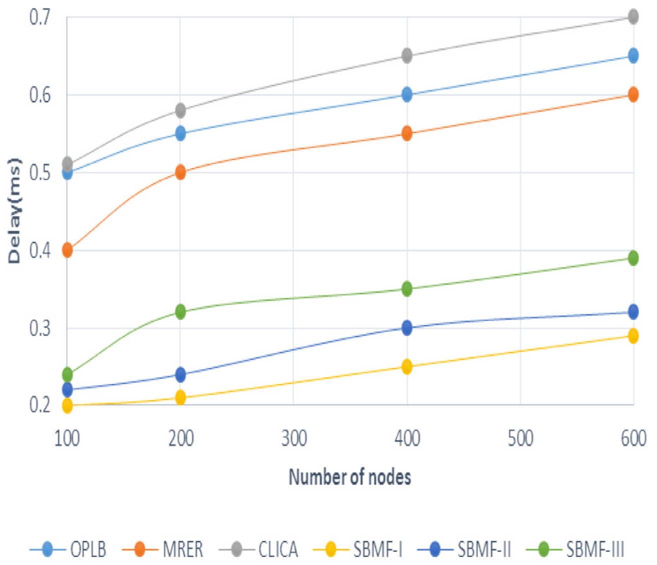

Fig. 9. Delay analysis.

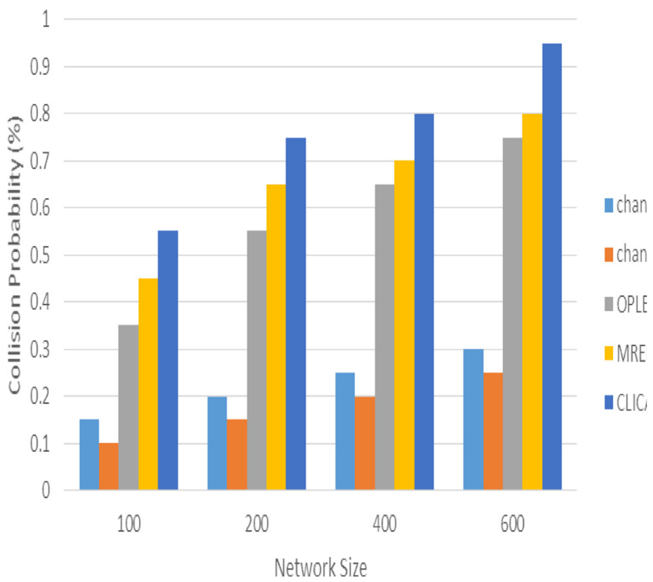

Fig. 10. Collision probability.

7. Conclusion

The inherent software module used in our approach to connect the Software-Defined Network allows the routing process varying from the existing methods. From the simulation results, it has been observed that the proposed scheme achieves the throughput of 2 Mbps and the delay of 0.3 s. The drop rate of the proposed algorithm is 40% and the delivery rate achieves 60%. Simulation results have shown that the proposed Software Based Multi Flow algorithm is used to increase the throughput and also to reduce the drop rate, collision probability, traffic rate, energy consumption and delay and hence reveals a multi-perspective performance improvement. Also, the scalability of the approach has also been tested by varying the size of the network. The scope of the proposed work can further be extended to handle hybrid, heterogeneous, unattended sensor networks, many application-specific constraints and their inherent trade-offs.

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