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Optimized Framework for QoS Efficient Routing Scheme in Wireless Mesh Network

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Abstract*: *Adoption of Wireless Mesh Network offers cost effective data transmission system; however, there is always a problems associated with larger scale of deployment where resource consumption is inevitable and beyond control. After reviewing the existing approaches toward improving the routing operation in Wireless Mesh Network, it has been seen that there are still a larger scope in improvement. Therefore, the proposed study introduces an optimized framework for quality of service that jointly works towards resolving hidden terminal problem as well as performs enhance data delivery in presence of challenging traffic scenario. The proposed system uses analytical modeling approach for channel occupancy is formulated and it performs computation of channel capacity. Further, an improved scheduling approach has been formulated in order to ensure superior saving of energy by considering various novel ranges of empirical parameters. Simulated in MATLAB, the proposed system highlights that it offers reduced delay, increased throughput, and highly controlled energy efficiency when compared with the existing routing protocols claims of traffic management in wireless mesh network.

Keywords: Wireless Mesh Network, Quality of Service, Traffic Management, Energy Efficiency, Bandwidth

I. INTRODUCTION

Wireless Mesh Network basically comprises of different nodes connected in the form of a mesh for data packet forwarding between the number of mesh clients and access point [1]. In the usual communication scenario, a mesh network consists of a client, routers, and gateway. The adoption of wireless mesh network can be seen in warehouse, healthcare sector, transport system, building automation, enterprise networking, etc [2][3]. The essential reason for the maximized adoption of wireless mesh network is due to its capability of facilitating the faster and reliable data transmission service [4]. However, the inherent working principle and layer-based structure of wireless mesh network is itself shrouded by various problems.

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The physical layer of wireless mesh network is featured with problems associated with adaptation of links, mobility, presence of multiple transceivers, feedback quality of link, fluctuation of transmission power etc [5]. The MAC protocol in wireless mesh network is also shrouded by various problems. The biggest problem is that the operation of the MAC protocol is restricted to single hop transmission only. In order to offers better data delivery services, it is required that communication to multiple numbers of hops as well as it is required to fully utilize the resources of the communication channel. The next part of the problem in wireless mesh network is associated with the network layer. Various problem associated with this layers are connectivity of mobile users, scalability and routing issue, quality of service, etc. With respect to transport layer, the problems still exists. It is already known that transport layer is not a preferred protocol while carrying out data forwarding operation in single hop network. Apart from this the problems associated with the transport layer is connected to level of power transmission, security, and provisioning. The level of energy required to carry out transmission should be either equal to or more than predefined existing network and so energy efficiency is biggest problem here. Apart from this, the most frequently discussed and concern problem in wireless mesh network is connected with the hidden terminal problem. This problem is found out to be less addressed problems in existing literatures [6]-[9]. The presence of hidden node could eventually lead to increased latency network where probability of collision as well as interference is quite high. Although, there are various theoretical solution claimed to overcome this problems e.g. adoption of omnidirectional antenna, removing all the impediments inspite of increasing node power level, utilization of the antenna diversity, etc. It has also been observed that provisioning of the Quality of Service (QoS) is quite essential when it comes to work over real-time communication. Unfortunately, the performance degradation occurs due to higher degree of fluctuation of the wireless communication path. In contrast to other adhoc network, the mesh network has higher scope of offering better provisioning of quality of service as the mesh routers are relatively static and hence it can offer highly stabilized mobility environment support too. However, due to communication medium being unreliable or delay of channel access being unpredictable, as well as due to different demands of quality of service, it is always a problem to offer better data transmission in mesh network. Therefore this paper presents a solution to this problem using optimization principle.

The organization of the proposed manuscript is as follows: Section-II discusses about existing literatures, Section-III discusses about research problem while discussion of adopted research methodology is carried out in Section IV. Design implementation is discussed in Section V while result analysis is carried out in Section VI. Finally, the summary of the contribution is carried out in Section VII.

II. RELATED WORK

This section is the continuation of the briefing of existing approaches of communication in wireless mesh network carried out in our prior work [10]. The recent work carried out by Rathan et al. [11] has presented a load balancing approach in wireless mesh network where an analytical approach has been used. The work is mainly focused on performing *traffic management in gateway* system where the author has used *swarm intelligence* with an objective function for delay reduction. The study outcome shows that it enhances the throughput performance in wireless mesh network which uses multiple radio as well as multiple channels. The work towards throughput improvement is also carried out by Yuhuai et al. [12] which have addressed the problem of *dependency of coding operation* while performing routing in wireless mesh network. The authors have mechanism a *routing policy with predefined information about the coding*. The work is simulated using network simulator where the outcome shows that it offers better opportunities toward routing with better throughput performance. Another work carried out by Islam et al. [13] has addressed the problem of *bottleneck situation* in wireless mesh network where undertaking better routing decision is prime issue. The authors have used non-linear programming where *reinforcement learning mechanism* for energy allocation as well as selection of link channel is used. The study outcome shows reduced delay as well as better throughput performance. A recent work carried out by Ebi et al [14] has taken a specific case study where loading condition in critical. The paper has addressed the problem associated with *loss of data packet* as well as *limited range of communication*. The author have used *multi-hop routing scheme* for offering better reliability of transmission in order to offer a better time synchronization. The system is meant for offering better data collection method. The study towards *reliability problem* was also carried out by Chen et al. [15] where the authors have presented an approach with better networking planning with least resources. The simulated outcome of the presented system shows better results in terms of latency.

The study towards improving the throughput and delay was always the primary concern in existing approaches. Study in such direction was carried out by Yaghoubi et al. [16] where the software defined network is used to develop architecture. The study has addressed *intermittent link breakage* that result in *data loss*. The solution is provides in this work in the form of optimal routing using *dynamic programming* in order to maintain better consistency form. Bao et al. [17] have developed an *adaptive* as well as *predictive* model that can perform an effective traffic management considering the case of mobility inclusion in it. The work carried out by Bao et al. [18] have presented an unique routing scheme where *symbols* were used for preventing *data loss* as well as it also *artificial intelligence* in order to perform selection of the routes. The work is mainly to address the issue of data throughput. The work carried out by Darroudi and Gomez [19] has presented a model establishing connection between the nodes within the Bluetooth network. This work has addressed the problems associated with *link connectivity in Bluetooth*-based communication over wireless mesh network. The solution is offered in the form of an analytical model where the *k-connected network* model is implemented. The work carried out by Liu et al. [20] has addressed the problem of *energy-based routing* when wireless mesh network is used with the Internet-of-Things. The presented solution is based on a unique mesh topology where the energy efficiency is carried out using a distributed manner. Another work carried out by Zhang et al. [21] have addressed the problem of *unstable links* in mesh network where the solution is presented using *Markov* modeling approach over multi-hop network. This model allows a dedicate communication channel in order to carry out transmission and its outcome was found to support futuristic communication protocols too. The work of Maccari et al. [22] has addressed the problem associated with *node failures* as well as *link failures* and issues associated with their recovery in mesh network. The author has presented a solution by using the centrality concept of the information of the node over the topology with a target to improve the *link state routing*. Sajjadi et al. [23] have carried out a study toward traffic engineering in mesh network where the emphasis was to address the problem associated with *cost effectiveness*. The authors have presented a selection of an efficient gateway system where the focus was mainly to improve the mechanism of the routing in the wireless mesh network in order to improve the traffic flow management. The study outcome shows that the presented mechanism offers better outcome when applied using *heuristic mechanism*. The study carried out by Choumast et al. [24] has focused on addressed forwarding *heavier multimedia data* over mesh network. The solution is provided with the help of opportunistic routing where the multi-hop approach was used with multicasting operation considering the case of video streaming. The study outcome shows better quality of signal transmission. Similar direction of study is also carried out by Al-Zubaidy et al. [25] where the idea is about achieving reliability towards video streaming process. The authors have used scalable video coding mechanism for this purpose. Hu et al. [26] have presented a *cross layer* based approach for addressing the problem associated with *energy efficiency* in wireless mesh network. The technique has used shortest path routing scheme with better duty cycle selection process considering case of social networks. Similar cadre of work is also carried out by Tu et al. [27] where a *multicasting process* has been used for video streaming over wireless mesh network. The technique uses a large scale routing using tree based approach. The work of Xu et al. [28] has used channel access-based approach in mesh network for improving the network capacity as well as for better scheduling of links. The model presented here claims of similar result as that of any centralized scheme with better packet delivery.

The work carried out by Chen et al. [29] have used MAC layer based scheme in order to address *energy dissipation* and *quality reduction* problem in mesh network when subjected to multimedia data delivery. The work of Chen et al. [30] have used opportunistic scheduling scheme which is meant for slot assignment in wireless network. Hence, existing system has various schemes toward addressing multiple problems in wireless mesh network.

III. RESEARCH PROBLEM

After reviewing the research approaches towards wireless mesh network, there are various research problems identified with respect to communication performance. This section briefs out the critical problems that has been identified in order to be addressed in proposed research work as follows:

- **Impact of Hidden Terminal**: None of the existing research work has actually focused on hidden terminal problem which is quite inevitable in case of large and dynamic scale of network. Presence of hidden terminal renders one node to communicate directly with one access point without establishing any form of communication with other nodes. Such problem may not so serious if the application demands passive data communication. However, for emergency based application, hidden node problem is quite critical. Hence, if this problem is sorted than there are good chances of increasing throughput of nodes in wireless mesh network.
- **Computation of precise channel capacity**: In all the existing studies that claims of using quality of service, the focus is more given to delay and less to bandwidth which is one of the critical resources. At present, there is no standard computational model to compute the exact bandwidth that is necessary to perform reliable data delivery. All the existing studies toward bandwidth computation has considered network layer however, it should be known that it is quite challenging to do so in the MAC layer. Hence, bandwidth as well as energy efficiency problem together has not been addressed in existing research work towards wireless mesh network.
- **Scheduling based Routing**: Scheduling and routing are always treated as different set of problems in wireless network. Existing approach using scheduling scheme offers quite sophisticated operation of routing where delay is mainly addressed at the cost of energy dissipation. Hence, it is needed that better scheduling practices be developed in order to manage the active and passive state of the nodes in wireless mesh network. Apart from this the routing approaches are developed quite on the basis of small number of factors. However, inclusion of small number of factors for routing over dynamic communication environment is quite a challenging task and there are good chances for error prone packet delivery.
- **Balancing the Significance of Forwarding**: Over a traffic system, there are various form of data as well as services. While some data are highly significant value and is anticipated to reach the access point at faster track while other data are normal. In existing approach, data prioritization scheme offers emphasis to only data to be forwarded first and doesn't offer emphasis to other form of data. In order to maintain an effective quality of service it is necessary that equal importance is given to all kinds of data.

Therefore, it can be seen that until and unless the above mentioned problems are solved, developing an effective routing scheme in wireless mesh network will be quite challenging. The next section discusses about the solution towards mitigation the above mentioned issues.

IV. RESEARCH METHODOLOGY

The prime aim of the proposed system is to develop a framework that can offer an effective data transmission system in wireless mesh network. The target is to achieve a resource efficient data transmission for better communication purpose in the form of optimization. Fig.1 highlights the design architecture of the proposed system, which exhibits that proposed system is carried out sequentially initially focusing on identifying hidden terminal issue followed by developing framework for enhanced routing policy.

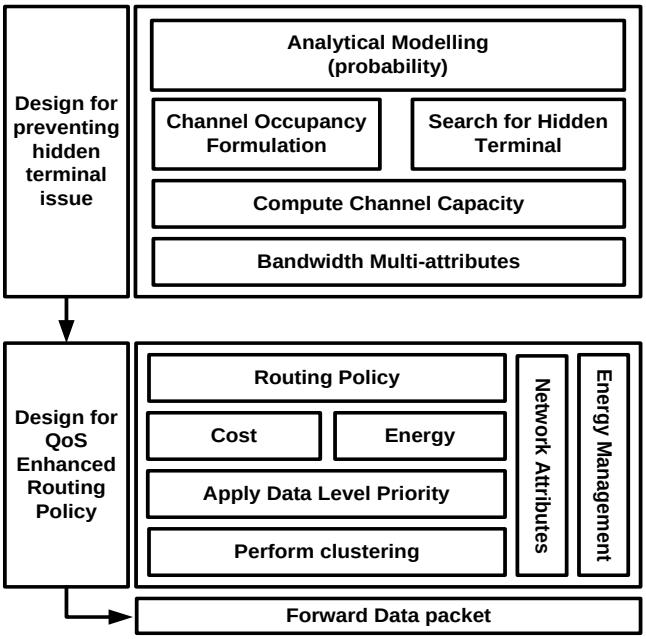

FIGURE 1 PROPOSED DESIGN ARCHITECTURE

The first block of implementation about hidden terminal pertains to identification and mitigating this problem. For this purpose, an analytical modeling is carried out using probability theory. The model implements logic for formulating channel occupancy along with a search for hidden terminal. Once the hidden terminal is explored, the next step will be to perform computation of the channel capacity that is required to perform successful data transmission This formulation is carried out using multiple attributes of the bandwidth utilization. The next block of implementation is about formulating the routing policy which after computation yields cost of routing as well as reduced energy factor considered for routing. This process is further followed by considering the level of data priority to ensure that proposed system do support emergency-based application over mesh network.

The process of data forwarding operation is further followed by a clustering operation to save energy. As a part of novelty, the proposed system considers various network attributes as well as energy management. Apart from this, the proposed system always make sure that all the participating nodes have enough energy conservation which is carried out by scheduling the time-slots for sleep and awake.

Hence, the proposed system introduces a concept of optimization without inclusion of any complex process. The target is to offer better routing scheme with optimized outcome of data delivery services.

V. DESIGN IMPLEMENTATION

The core concept of the proposed design implementation is based on the fact that there is a need to develop a novel communication scheme in wireless mesh network. The essential criteria in the design are to incorporate better form of communication protocol with superior Quality of Service (QoS) in it. For this purpose, the complete work is developed in two sequential processes in order to achieve the research objective. The complete design is splitted in two parts viz. i) design for preventing hidden terminal issue and ii) design for QoS enhanced Routing policy. This section discusses about the design aspects involved in this process.

A. Design for Preventing Hidden Terminal Issue

This is the first part of implementation which builds up an analytical model in order to address hidden terminal problem as a medium to improve communication performance in wireless mesh network. More detail about this part of implementation is presented as follows:

i) Aim: The core aim of this part of implementation is to identify and isolate any presence of hidden terminal so that data delivery can be improved.

ii) Problem Addressed: Majority of the wireless mesh network application needs to be operated over dynamic environment. In such environment, there are fair chances of presence of hidden terminal node, which is found less to be considered in literatures too. Therefore, without such consideration, it is quite challenging to assess the impact of network factors e.g. bandwidth, energy, etc over network performance. Hence, the core problem addressed here is identification and isolation of hidden node problem in wireless mesh network.

iii) Design Implementation: The proposed system makes use of probability theory in order to formulate design model for bandwidth evaluation (Fig.2). The network parameters e.g. number of nodes and area of deployment are initialized followed by construction of a unique control message. The evaluation of the bandwidth is carried out with respect to three attributes viz. i) maximum bandwidth, ii) utilized bandwidth, and iii) available bandwidth. With the aid of occupancy rate of channel and identity of node, the proposed system computes the channel capacity considering the temporal attribute of data transmission. The contribution of this process is that it carries out on-demand routing using different probability attributes e.g. state of collision, successful state of delivery, and idle state of node. The complete algorithm also considers mobility state of node.

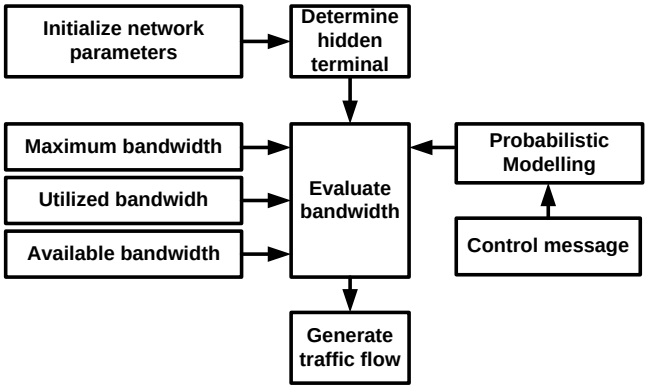

FIGURE 2 DESIGN IMPLEMENTATION OF 1ST MODULE

B. Design for QoS Enhanced Routing Policy

This is the continuation of the prior implementation where bandwidth computation is carried out in novel manner by resisting the hidden terminal. The inclusion of this part of implementation is performing communication using multihop routes, resisting bottleneck condition, and management overall traffic behaviour. All these contribute toward enhanced routing policy that finally results in better achieving of QoS.

i) Aim: The core aim of this part of implementation is to offer a seamless data transmission in wireless mesh network with significant saving of resources

ii) Problem Addressed: Assuming that hidden terminal issue is solved and the system is capable of estimating precise bandwidth, still it could need to be more capable to sustain uneven traffic management. There is a fair chances that the system fails to identify the real demands of traffic and performs error-prone routing in wireless mesh network. Hence, there is need to consider all this uncertain probabilities while developing a routing policy to offer better QoS.

iii) Design Implementation: This part of the design implementation considers new parameters apart from the similar parameters used in prior module of implementation (Fig.2). The new parameters are beacon arrival time, priority level of data packet, time slots, and active transmission time. All these parameters have a significant impact on the design of routing policy to ensure QoS. The proposed system formulates routing with respect to reduced cost (amount of resources) and energy consumption. The significant novelty of this part of implementation are i) the routing performance is stabilized in presence of dynamic by assigning beacon arrival span which is a duration to govern forwarding control message, ii) assigning priority level ensures urgent data packet to be forwarded over dedicated channel without affecting the normal packet data transmission, iii) assigning a time slots assists in effective routine maintaining for sleep, awake, and idle state of node, iv) and active transmission time assist in updating the system about successful data transmission with better throughput, v) the design also offers a consistent forwarding of the update message in order to resist any form of stale routing information, vi) the inclusion of clustering further assists in structured forwarding of data to the access point further saving more energy.

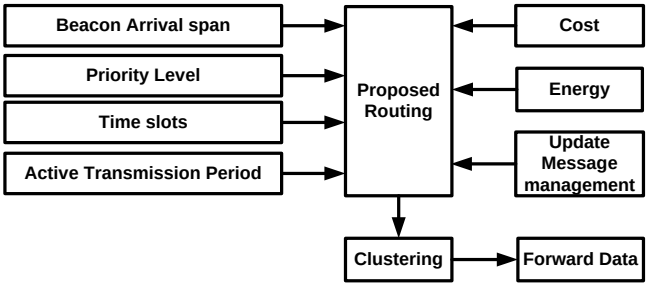

Figure 3 Design Implementation of 2nd Module

This part of the design offers balance for meeting communication demands over peak traffic condition as well as potential saving of energy factor of nodes and significantly other resources too (like memory). Hence, an improved QoS demands are actually met in the process of forwarding the data packet efficiently.

VI. RESULT ANALYSIS

The analysis of the outcome of the proposed system is carried out considering following simulation environment viz. 60 nodes dispersed in random location in presence of an access point, 224 bits of MAC header, and 192 bits of physical header, 150 kbps of channel capacity, and following IEEE 802.11 standards. The scripting of the proposed logic is carried out in MATLAB.

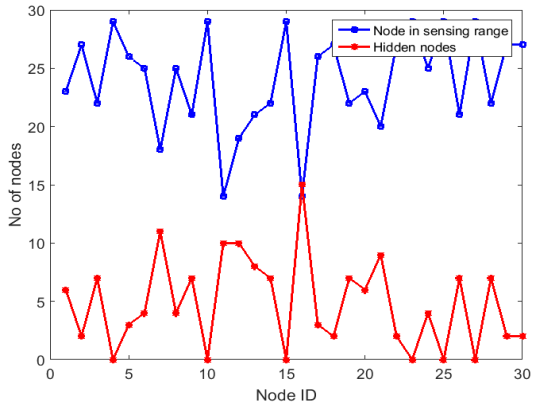

FIGURE 4 ANALYSIS OF HIDDEN NODES

A closer look into Fig.4 highlights that proposed system is capable of identifying the hidden terminal and their possibilities towards obstructing the data communication in wireless mesh network. Fig.4 also shows that number of such hidden nodes, once found, is reduced in number in contrast to the nodes that are in sensing range.

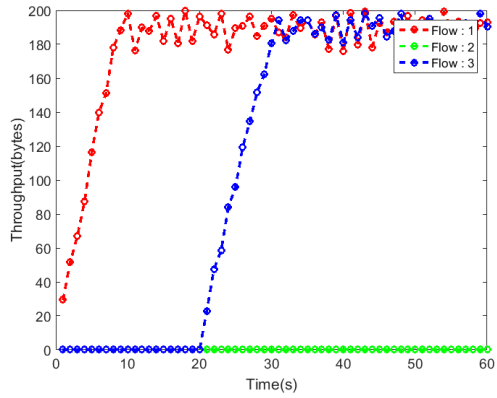

Figure 5 Throughput Performance

Fig.5 highlights the throughput performance in presence of three different traffic flows. Traffic flow-1 is for normal traffic, traffic -2 is for abnormally heavy traffic, and traffic-3 is for medium-heavy traffic which is meant for saturating the complete bandwidth. The outcome shows that proposed system holds good (proper identification and removal of hidden terminal) for both traffic flow-1 and traffic flow-3. However, the throughput significantly degrades to traffic flow-2; however, it will be compensated by performing further retransmission operation followed by allocation the same traffic upon finding route with required bandwidth. Hence, the 1st framework is capable of identifying and mitigating hidden node terminal but it still requires sustaining dynamic traffic condition where the bandwidth demand is very high. This challenge is addressed in second framework which emphasizes over the QoS factors. The second framework completes the entire research objective and hence it is benchmarked using existing SOAR [31] protocol and ROMER [32] protocol with respect to various performance parameters.

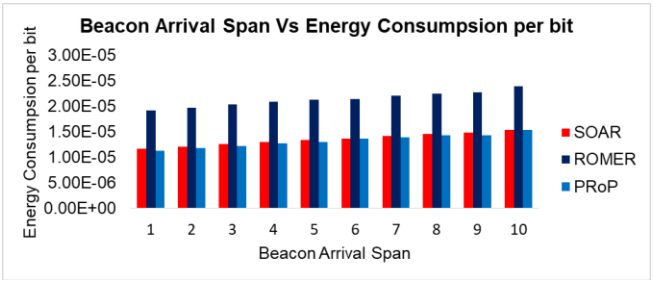

Figure 6 Comparative Analysis of Energy

Fig.6 shows that proposed system offers better energy reduction capability upon increasing traffic scenario (i.e. beacon arrival span) in contrast to existing protocol. The prime reason behind it is that proposed system offers routing on the basis of reduced cost and energy which cannot be seen in SOAR and ROMER. Apart from this, much energy is saved as proposed system uses time slot management for MAC protocol for scheduling the complete data transmission.

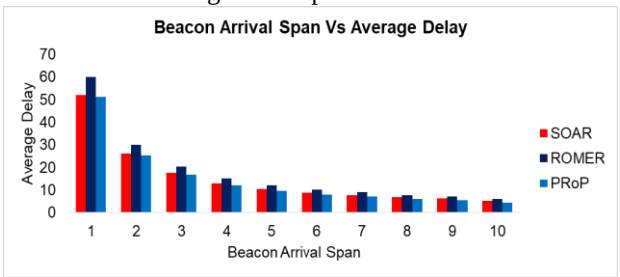

Figure 7 Comparative Analysis of Delay

It should be noted that proposed system has less involvement of any recursive based operation in order to establish communication. Although adaptive in nature, SOAR protocol offers inclusion of identification of loss packet which consumes slightly more time. ROMER reduces overhead but it includes more operation towards identify candidate nodes without an form of updates.

Hence, there is no reliability of the routes to carry fresh data in existing system whereas proposed system maintains reduced delay and always update the route information upon every transmission.

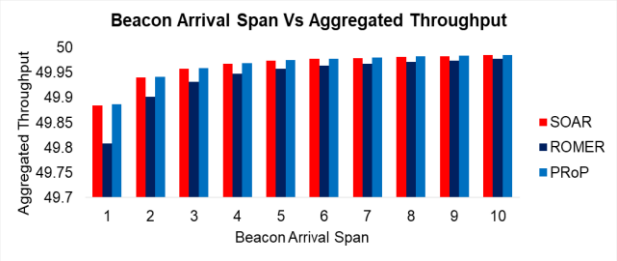

Figure 8 Comparative Analysis of Throughput

Fig.8 highlights the throughput performance where proposed and SOAR are seem to offer nearly similar scores. However, it should be noted that SOAR doesn't offer energy efficiency irrespective of it being adaptive in nature. ROMER uses a credit-based approach which is not meant for concurrent traffic management especially where the network is of dynamic nature. Therefore, the results showcase that proposed system offers better throughput performance in contrast to existing approach.

VII. CONCLUSION

This paper has presented a mechanism that is capable of maintaining a better form of data transmission along with optimized saving of the resources. The core contribution of the proposed study are as follows: i) the proposed system successfully identify and isolate the hidden terminal without affecting the existing ongoing communication, ii) elimination of hidden terminal results in increased data delivery service and more participation of the nodes, iii) effective scheduling offer better time-slot routine management of periodic wake-up and sleep state, which curtails maximum energy during the communication, iv) the proposed system significantly optimizes the data delivery services without any inclusion of sophisticated approaches.

REFERENCES

1. Sinha, Santanu, Robert B. O'Hara Jr, and Shahriar I. Rahman. "Centrally controlled routing with tagged packet forwarding in a wireless mesh network." U.S. Patent 7,839,856, issued November 23, 2010.
2. Seyedzadegan, Mojtaba, Mohamed Othman, Borhanuddin Mohd Ali, and Shamala Subramaniam. "Wireless mesh networks: WMN overview, WMN architecture." In International conference on communication engineering and networks IPCSIT, vol. 19, p. 2. 2011.
3. English, Kent L., and Christopher K. Zuver. "Mobile wireless mesh technology for shipping container security." U.S. Patent 7,522,043, issued April 21, 2009.
4. Jung, Ji-Sun, Keun-Woo Lim, Jae-Beom Kim, Young-Bae Ko, Younghyun Kim, and Sang-Yeom Lee. "Improving IEEE 802.11 s wireless mesh networks for reliable routing in the smart grid infrastructure." In 2011 IEEE international conference on communications workshops (ICC), pp. 1-5. IEEE, 2011.
5. Shabdanov, Samat, Patrick Mitran, and Catherine Rosenberg. "Cross-layer optimization using advanced physical layer techniques in wireless mesh networks." IEEE Transactions on Wireless Communications 11, no. 4 (2012): 1622-1631.
6. Tsai, Tzu-Jane, and Ju-Wei Chen. "IEEE 802.11 MAC protocol over wireless mesh networks: problems and perspectives." In 19th International Conference on Advanced Information Networking and Applications (AINA'05) Volume 1 (AINA papers), vol. 2, pp. 60-63. IEEE, 2005.
7. Li, Chi-Yu, An-Kai Jeng, and Rong-Hong Jan. "A MAC protocol for multi-channel multi-interface wireless mesh network using hybrid channel assignment scheme." Journal of Information Science and Engineering 23, no. 4 (2007): 1041-1055.
8. Koutsonikolas, Dimitrios, Theodoros Salonidis, Henrik Lundgren, Pascal LeGuyadec, Y. Charlie Hu, and Irfan Sheriff. "TDM MAC protocol design and implementation for wireless mesh networks." In Proceedings of the 2008 ACM CoNEXT Conference, pp. 1-12. 2008.
9. Jun, Jangeun, and Mihail L. Sichitiu. "The nominal capacity of wireless mesh networks." IEEE wireless communications 10, no. 5 (2003): 8-14.
10. Naveen, T. H., and G. Vasanth. "Qualitative study of existing research techniques on wireless mesh network." International journal of advanced computer science and applications 8, no. 3 (2017): 49-57.
11. Rathan, Karunya, SusaiMichael Emalda Roslin, and Easpin Brumancia. "MO-CSO-based load-balanced routing in MRMC WMN." IET Communications 13, no. 16 (2019): 2453-2460.
12. Yuhuai, P. E. N. G., D. E. N. G. Qingxu, G. U. O. Lei, and W. A. N. G. Fanzhao. "A new network coding based routing protocol for enhancing throughput capacity in wireless mesh networks." Chinese Journal of Electronics 28, no. 2 (2019): 416-422.
13. Islam, Maheen, Selina Sharmin, Fernaz Narin Nur, Md Abdur Razzaque, Mohammad Mehedi Hassan, and Abdulhameed Alelaiwi. "High-Throughput Link-Channel Selection and Power Allocation in Wireless Mesh Networks." IEEE Access 7 (2019): 161040-161051.
14. Ebi, Christian, Fabian Schaltegger, Andreas Rüst, and Frank Blumensaat. "Synchronous LoRa mesh network to monitor processes in underground infrastructure." IEEE Access 7 (2019): 57663-57677.
15. Chen, Qian, Xiao Juan Zhang, Wei Lih Lim, Yuen Sam Kwok, and Sumei Sun. "High Reliability, Low Latency and Cost Effective Network Planning for Industrial Wireless Mesh Networks." IEEE/ACM Transactions on Networking 27, no. 6 (2019): 2354-2362.
16. Yaghoubi, Forough, Marija Furdek, Ahmad Rostami, Peter Öhlén, and Lena Wosinska. "Consistency-Aware Weather Disruption-Tolerant Routing in SDN-Based Wireless Mesh Networks." IEEE Transactions on Network and Service Management 15, no. 2 (2018): 582-595.
17. Bao, Ke, John D. Matyjas, Fei Hu, and Sunil Kumar. "Intelligent software-defined mesh networks with link-failure adaptive traffic balancing." IEEE Transactions on Cognitive Communications and Networking 4, no. 2 (2018): 266-276.
18. Bao, Ke, Fei Hu, and Sunil Kumar. "AI-Augmented, Ripple-Diamond-Chain Shaped, Rateless Routing in Wireless Mesh Networks With Multibeam Directional Antennas." IEEE Access 6 (2018): 24311-24324.
19. Darroudi, Seyed Mahdi, and Carles Gomez. "Modeling the connectivity of data-channel-based bluetooth low energy mesh networks." IEEE Communications Letters 22, no. 10 (2018): 2124-2127.
20. Liu, Yu, K-F. Tong, and K-K. Wong. "Reinforcement learning based routing for energy sensitive wireless mesh IoT networks." Electronics Letters 55, no. 17 (2019): 966-968.
21. Zhang, Chen, Cheng Li, and Yuanzhu Chen. "A markov model for batch-based opportunistic routing in multi-hop wireless mesh networks." IEEE Transactions on Vehicular Technology 67, no. 12 (2018): 12025-12037.
22. Maccari, Leonardo, and Renato Lo Cigno. "Improving Routing Convergence With Centrality: Theory and Implementation of Pop-Routing." IEEE/ACM Transactions on Networking 26, no. 5 (2018): 2216-2229.
23. Sajjadi, Dawood, Rukhsana Ruby, Maryam Tanha, and Jianping Pan. "Fine-grained traffic engineering on SDN-aware Wi-Fi mesh networks." IEEE Transactions on Vehicular Technology 67, no. 8 (2018): 7593-7607.
24. Choumas, Kostas, Ilias Syrigos, Thanasis Korakis, and Leandros Tassiulas. "Video-aware multicast opportunistic routing over 802.11 two-hop mesh networks." IEEE Transactions on Vehicular Technology 66, no. 9 (2017): 8372-8384.
25. Al-Zubaidy, Hussein, Viktoria Fodor, György Dán, and Markus Flierl. "Reliable video streaming with strict playout deadline in multihop wireless networks." IEEE Transactions on Multimedia 19, no. 10 (2017): 2238-2251.
26. Hu, Jie, Lie-Liang Yang, and Lajos Hanzo. "Energy-efficient cross-layer design of wireless mesh networks for content sharing in online social networks." IEEE Transactions on Vehicular Technology 66, no. 9 (2017): 8495-8509.

27. Tu, Wanqing, Cormac J. Sreenan, Sanjay Jha, and Qian Zhang. "Multi-source video multicast in Internet-connected wireless mesh networks." IEEE Transactions on Mobile Computing 16, no. 12 (2017): 3431-3444.
28. Xu, Yuanhuizi, Kwan-Wu Chin, and Sieteng Soh. "A Novel Distributed Pseudo-TDMA Channel Access Protocol for Multi-Transmit-Receive Wireless Mesh Networks." IEEE Transactions on Vehicular Technology 67, no. 3 (2017): 2531-2542.
29. Chen, Shengyang, Zhenhui Yuan, and Gabriel-Miro Muntean. "Balancing energy and quality awareness: A MAC-layer duty cycle management solution for multimedia delivery over wireless mesh networks." IEEE Transactions on Vehicular Technology 66, no. 2 (2016): 1547-1560.
30. Chen, Weiwei, Chin-Tau Lea, Shiming He, and Zhe XuanYuan. "Opportunistic routing and scheduling for wireless networks." IEEE Transactions on Wireless Communications 16, no. 1 (2016): 320-331.
31. Rozner, Eric, Jayesh Seshadri, Yogita Mehta, and Lili Qiu. "SOAR: Simple opportunistic adaptive routing protocol for wireless mesh networks." IEEE transactions on Mobile computing 8, no. 12 (2009): 1622-1635.
32. Yuan, Yuan, Hao Yang, Starsky HY Wong, Songwu Lu, and William Arbaugh. "ROMER: Resilient opportunistic mesh routing for wireless mesh networks." In IEEE workshop on wireless mesh networks (WiMesh), vol. 12. 2005.

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