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RESEARCH ARTICLE

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L-RUBI: An efficient load-based resource utilization algorithm for bi-partite scatternet in wireless personal area networks

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Summary

Recently, much of the wireless personal area network (WPAN) research concerns network protocols, scheduling, and security challenges but the major issue of resource utilization has been very rarely investigated. The design of resource sharing in a network gets more attention when the number of users increases. While optimizing performance, resource utilization plays a critical role. In this paper, the numerical performance of a wireless resource utilization algorithm for a bi-partite scatternet is presented. This algorithm is focused to enhance the bandwidth allocation and power utilization of wireless scatternets. Every node can communicate with a single neighbor at a time with minimum resources. Finally, the performances of the RUBI algorithm are shown. This algorithm is compared with the existing algorithms such as the load adaptive scheduling algorithm and pseudorandom coordinated scheduling scheme in terms of various parametric metrics like reliability, throughput, collision probability, transmission probability, and signal-to-noise ratio (SINR). The proposed L-RUBI achieves 93.4% of reliability, 93.6% of transmission probability, 91.4% of throughput, 76.8% of collision performance, and 72.2% SINR.

KEYWORDS

bandwidth allocation, bi-partite scatternet, power utilization, resource sharing, resource utilization algorithm, scatternet, wireless personal area networks

1 | INTRODUCTION

In recent times, more specific research topics have been initiated for the development of wireless personal area networks (WPAN).[1] Most of them use functional electronic gadgets like mobile phones, portable laptops, and personal digital assistants to exchange information wirelessly with the efficient help of short-range radio links.[2] These radio links properly employ frequency hop spread spectrum scheme for multiple channel allocation.[3] Every local channel divided into 625-μs time intervals is called slots, where the direct communication promptly initiated among the responsible master to a willing slave is called upstream transmission.[4] It is operated efficiently in the even-numbered interval. The standard transfer between freed slaves to a master is naturally called downstream transmission.[5] It is operated properly in the odd-numbered interval. All details are only exchanged by connecting a master and a ready slave, that is, there is no direct data communication between willing slaves.[6]

Every prime slot typically consists of information packages. The media information packages are supportive of synchronous transfer, and the data packets are helpful for variable asynchronous transfer.[7,8] The synchronous transfer takes existing reserved bandwidth but asynchronous transfer uses time division duplex method to utilize unreserved bandwidth slots.[9] The unique combination of established master and slave devices is called piconet, where a single master controls all slaves (maximum 7 slaves in a piconet).[10] The combination of more than one piconet is typically called scatternet.[11] Wireless naturally follows the essential messages based on direct communication over proper time-slotted links, which instantly connect different piconet in a scatternet.[12] The fast automatic repeat request, cyclic redundancy check, and forward error correction schemes help to identify the usage of resources.[13] On time-sharing basis, an established master or a slave present in various piconet. These specific devices are typically referred to as local bridges of scatternet. Wireless scatternet presents different power reduction schemes (hold, park, and sniff), which are used to decrease the duty cycle of nodes.[14] When a bridge (either master or slave bridge) is active in a piconet and inactive in another neighbor piconet, the power reduction schemes (hold and sniff modes) are used for inter-piconet communication.[15,16]

Resource utilization and sharing in network are focused on finding the feasible set of node capacities that satisfies the requirements of a network.[17] If a node is typically connected to more than one piconet, it operates in various frequencies, and their timing and hop selection are autonomous of each node.[18] This is the key reason why a scatternet presents upper combined bandwidth compared with a single piconet. The master decides the bandwidth allocation and schedule the network traffic within a piconet.[19] Enhanced resource utilization schemes are focused on efficient bandwidth allocation, low power utilization, increased network speed, reduced time delay, and suitable path for the network traffic supplies.[20]

The primary focus of this paper is described as follows.

- Network users are usually divided into primary and secondary user categories. It is important to determine their resource needs and allocate resources accordingly. The primary purpose of this paper is to identify network users and allocate resources to meet their needs.
- A limited number of users should be given a pass-code to access network resources. It should be designed to vary according to the needs of the primary user and the secondary user.
- If the number of users is close to a certain level, then the number of users on the network will be neutral
- When the resources are allocated according to the user's needs, scheduling should be done in such a way as to provide them immediately.
- When there are scarce resources, they should be calculated immediately and it will be retransmitted according to the user's needs.

This paper is structured as follows; Section 2 outlines the existing works related to the resource utilization schemes. Section 3 explains the problem of scatternet resource utilization in bipartite graphs. Section 4 provides the detailed analytical simulations of the proposed model. The comparative analysis is presented in Section 5. Finally, conclusions and future works are explained in Section 6.

2 | RELATED WORKS

In general, resources are allocated to each user in a WPAN according to their needs. Most existing systems allocated resources without considering the needs of the user, resulting in excess resources being wasted and resources not being allocated to other users. It creates a situation where users are faced with many inconveniences. As such, some of the research below provides information on resource allocation currently being practiced.

A. Moravejosharieh et al.[21] examined the various performance evaluations in IEEE 802.15. 4. The authors have measured efficiency using passive and active methods in this research. Both ways analyze the use of the same frequency spectrum between body sensor networks and exploit the interference effect of sensor nodes when necessary. The resource optimization problem occurs instantly under various conditions of different scatternet topology formations. The flow deflection has highlighted where each repetition correctly finds the possible outflow direction by uniquely identifying the narrowest path. Furthermore, research results have shown that active programs in this proposed manner have significant performance gains. Madheswaran et al.[22] discussed a dynamic cluster head selection algorithm for LEACH protocol in wireless sensor networks. In this way, the authors investigated the sharing of resources among the sensor nodes between the clusters. They introduced a D-LEACH method to limit sharing between sensor nodes during cluster head selection in these algorithms that need to fix promptly a matching the specific max-weight issue for every possible repetition. It should solve a trouble bipartite max-weight matching efficiently once it has applied precisely for suitably rectifying the fundamental problem of scatternet resource utilization (SRA). Logeshwaran et al.[23] investigated various adaptive scattering and resource allocation scheduling approaches for ScatterNet. This approach analyzed randomly designed scatternet standard topologies. As a result, 94.94% of bandwidth resources have utilized. Moreover, 92.09% of the sensor nodes have used the resources for data transfer. Also, the channel width has increased to 93.46%. Through this, it is possible to achieve high utilization of the resources used by the sensor nodes while communicating in higher transmission mode.

Choudhury et al.[24] discussed that a beacon synchronization scheme efficiently helps and reasonably achieves fundamental fairness of other nodes that can reallocate unused bandwidth. In this method, the authors have proposed the localized beacon synchronization method. In this method, the cluster-tree network performs improved features to overcome various problems through synchronization due to beacon scheduling occurring in different topologies. In this method, 2-hop information is used to calculate offsets related to beacon transmission. And these methods exhibit high levels of performance over the running time intervals. It has been calibrated to significantly reduce resource allocation overhead when synchronization operations between different devices on the network change. Kiruthiga et al.[25] illustrated that the resource utilization of various nodes (r_1, r_2, r_3 … .r_n) is achieved if the scatternet network is a bipartite graph. This can possible if the sum of resources in all intervals transverse the node is ≤ 1. Resource utilization for non-bipartite graphs can be reached if the sum of resources in all intervals transverse the node is $\leq 2/3$. Because of guard time, a bandwidth loss occurs in the scatternet. The minimum average service time has been adequately introduced to increase the optimal performance. Choudhury et al.[26] presented a non-threshold-based cluster-head rotation scheme. In this research, they have calculated the threshold energy level required for cluster head rotation. Here, some limitations followed in the cluster head resource allocation methods periodically. Here the non-threshold CH cycle scheme (NCHR) method is proposed. In this method, minimum cycles are followed for resource allocation in the network. This way, the topological changes and the diversity of the sensor nodes are improved. In this research, the network performance and its lifetime are also increased.

Khan et al[27] presented the difficulty of an Efficient and reliable hybrid deep learning-enabled model for a particular repetition. The efficient flow of the data packets typically stands in the local need of uniquely designed scatternet scheduling algorithms. These efficient algorithms typically schedule and carefully coordinate bridges' active presence within the scatternet. The primary advantage of this crucial algorithm is that it typically gains the frequent use of the wireless low-power hold mode, which ideally allows more flexibility than other modes.

Valkanis et al.[28] introduced a scheduling algorithm named pseudo random coordinated scheduling algorithm (PCSS) for efficient resource utilization in wireless scatternet. This algorithm capably organizes data transmission in wireless scatternets. The pseudo-random sequences mechanism helps the meeting junctions to eliminate collision, and algorithm protocols control the meeting junction intensity without any prior intimation. However, the ideal scheduler and PCSS utilized equal power to reach similar throughput. Bamber et al.[29] discussed a modified adaptive mechanism for optimizing IEEE 802.15. 4 WPANs for wireless sensor networks. They expressed that resource allocations in the network are based on the needs of the sensor nodes traveling there. These vary from node to node. When proper resources are allocated, the transmission will be faster. Transmission occurs with a slight delay when there is a shortage in resource allocation.

Kempanna et al.[30] provided an intelligent design of an efficient binary phase-shift keying based on IEEE 802.15. 4 transceiver architecture and its performance analysis. When the allocated resource is increased at a given location, sensor nodes' chance of wasting those resources increases. As a result, other nodes have scarce resources, and their performance slows down. Thus, it is necessary to allocate resources at the right level to the correct nodes. Sreelatha et al.[31] expressed a spectrum relay performance of cognitive radio between users with random arrivals and departures. When spectrum allocations are defined based on the primary user, there are many spectrum vacancies. Secondary user operations can also fill in the vacant slots connected to that spectrum band to achieve maximum efficiency and resource utilization. Thus spectrum allocation is based on the random arrivals and departures method, and that spectrum can achieve high efficiency.

The summary of the existing works are illustrated in the Table 1. These related works have some notable advantages and drawbacks. Based on the drawbacks, the proposed models were discussed in the upcoming Section 3.

The problems found to be important in the previously reported methods are mentioned below:

TABLE 1 Summary of the related works

S.no	Authors	Advantages	Drawbacks
1	Moravejosharieh et al.[21]	Flow deflection algorithm was highlighted where each repetition properly finds the possible outflow direction	The resource optimization problem occurs instantly under various conditions
2	Madheswaran et al.[22]	This model solves the efficiently a trouble bipartite max-weight matching	Max-weight issue occurs for every possible repetition
3	Logeshwaran et al.[23]	An adaptive scatternet scheduling approach provides the valid scheduling between the users	The configuration of different traffic conditions of scatternet was too difficult
4	Choudhury et al.[24]	The beacon synchronization scheme efficiently helps and reasonably achieves fundamental fairness of other nodes	Here, the Minimum average service time was properly managed. So the users can wait some minimum duration to utilize the resources
5	Kiruthiga et al.[25]	Resource utilization of various nodes is achieved if the scatternet network using a bipartite graph	Resource utilization for non-bipartite graphs are not obtained the maximum results
6	Choudhury et al.[26]	The frequent use of the Wireless low-power hold mode, which ideally allows more tremendous flexibility than other modes.	The mode selection and changing has some waiting time of the nodes.
7	Khan et al.[27]	The beacon synchronization scheme efficiently helps and reasonably achieves fundamental fairness	There is no central authority for monitoring the initial flow rate values and link capacity of the node
8	Valkanis et al.[28]	This PCSS algorithm capably organizes data transmission in wireless scatternets	The ideal scheduler and PCSS utilized equal power to reach similar throughput
9	Bamber et al.[29]	The resource allocations in the network are based on the needs of the sensor nodes traveling	When there is a shortage in resource allocation, transmission takes place with a slight delay
10	Kempanna et al.[30]	An efficient binary phase-shift keying based on transceiver architecture provides the better resource sharing between the transmitter and receiving nodes	The allocated resource is increased at a given location, the chances of sensor nodes wasting those resources increase
11	Sreelatha et al.[31]	The secondary user operations can also fill in the vacant slots connected to that spectrum band to achieve maximum efficiency and resource utilization	When spectrum allocations are defined based on primary user there is a large number of spectrum vacancies

1. Interference from unknown devices in the WPAN consumes a lot of network resources. This causes problems in providing sufficient resources to the users who need them.
2. Excessive use of unidentified devices not only slows down the network but also causes inconvenience to other users. This will reduce the number of primary users of the network.

Load-based resource utilization algorithm is proposed to avoid such problems. Through this, excessive users in a network cluster can be identified and resource allocation can be done for them.

3 | SCATTERNET RESOURCE UTILIZATION PROBLEM

Consider a scatternet graph A, which connects the different nodes but undirected. $A = (L, R)$. L will indicate the set of undirected nodes $L = \{1, 2, 3 \ldots .n\}$. These nodes may be a bridge or an individual of master and slave. R will indicate the bi-directional links, where the endpoints are denoted by (x, y). For each node in endpoint x denoted by $Z(x)$, which shows the group of nearest neighbor nodes. The real-time WPAN network resource allocation was shown in Figure 1. Let P_v be the average bi-directional flow on a link v and Q_v be the capacity of the link (the units of P and Q are bits per second). The average flow in a bi-directional link in a positive manner on every node is assumed ($P_v > 0$, ✯ $v \in R$); therefore, flow on a node v (p_v) is the ratio between the average flow of bi-directional link (P_v) and the most probable flow on a node.

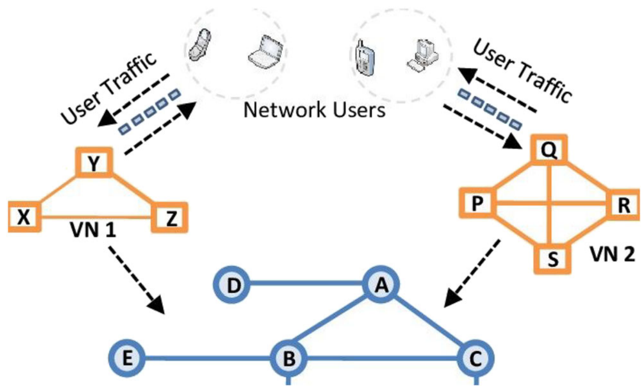

FIGURE 1 Real-time WPAN network resource allocation.

The major purpose of the resource utilization algorithms is to reduce the amount of decreasing non-linear functions of the various nodes' capacities. The topology was structured, and the flow rate (p_v) of a node is given. The average delay (q_v) was minimized to find the capacities (q_v) of a node. Because of resource utilization problem in bipartite graphs of a scatternet, the following was prepared:

$$\text{Minimize the average delay} \sum v_{\in R}\,(\mathrm{q}_v) \tag{1}$$

Definition 1. Capacity of the node (q_v) always greater than the flow rate of the node (p_v) for all repetitions, where the node v is an element of a bi-directional link.

$$q_v > p_v \bigstar \mathrm{v} \in R \tag{2}$$

Definition 2. The max-link capacity (q_v) of node v cannot exceed the total capacity.

$$\sum v \in (\mathrm{i})^{\mathrm{q}} v \leq 1 \quad \bigstar \quad \mathrm{i} \in L \tag{3}$$

The problem formation in terms of an assumption, is that the flow rates (p_v) of a node v are specified by the upper layer protocols, based on different scatternet traffic. Resource utilization is possible if it satisfies the following two limitations.

Definition 3. Consider α is a resource utilization factor, now the resource utilization of all nodes. (r_1, r_2, r_3 … .r_n) is achieved in the sum of resources of all intervals is ≤α.

$$\text{Node capacity constraint} = \frac{\mathrm{a} \leq 1; \text{for bipartite graphs}}{\{\mathrm{a} \leq \frac{2}{3}; \text{for non-bipartite graphs}}$$

Definition 4. The bandwidth is always less than or equal to the produced packet rate. If an interval i produces packets at the rate (ρ_i) and its bandwidth (β_i) is enclosed with produced packets (ρ_i). Based on *Edmond theorem*[5] and the analysis of *Bruce Hajek and Galen Sasaki's*[4] constraints, the above equation (3) was modified because of non-bipartite graphs.

$$\sum_{v \in (\mathrm{i})} q_v \leq \tfrac{2}{3} \;\star\; \mathrm{i} \in L \tag{4}$$

The above equation (4) is the suitable condition for resource utilization for non-bipartite graphs. The slack capacity nodes reduced the performance of a scatternet. Because of these nodes, the utilization of various resources increased. It takes much time during the continuous process of instantly moving a key bridge from one piconet to another. In case the nodes are non-bipartite, then the slack capacity of a node s_i can be defined as the following:

$$^{s}\mathrm{i}^{=2/3-}\sum v \in (\mathrm{i})^{\mathrm{q}} v$$

This problem resource utilization for bi-partite scatternet for slack capacity nodes (s_i) declared as

$$^{s}\mathrm{i}^{=1-}\sum v \in (\mathrm{i})^{\mathrm{q}} v \tag{5}$$

In the initial condition, all the flow rates are equal (p_v) to the capacity of nodes (q_v) for all bi-directional links. So the flow rate (p_v) values added instead of (q_v) in equation (5).

$$^{s}\mathrm{i}^{=1-}\sum v \in (\mathrm{i})^{p} v \tag{6}$$

The maximum resource utilization of a node (r_v) is the difference between the capacity of a node and the flow of a node for all the bi-directional transfer. The maximum resource utilization of a node (r_v) is achieved in terms of slack capacity node (s_i) as follows:

$$r_v = \mathrm{q}_v - p_v \quad \star \mathrm{v} = R \tag{7}$$

The formation of the problem resource utilization in a bi-partite scatternet was obtained from equation (1). Consider the node v is a bi-directional node of R. The sum of bi-directional nodes allows bi-directional flow of packets. Now the problem was formed to minimize the maximum resource utilization (r_v) of a bi-directional node v.

$$\text{Minimize the resource utilization of a node } v, \sum_{\mathrm{v} \in R} (r_v) \tag{8}$$

Limitation 1: The maximum resource utilization (r_v) is always less than or equal to the slack capacity (s_{i}) of the node, where the slack capacity node i is a member of L.

$$\sum v \in (\mathrm{i})^{r} v \leq s_{\mathrm{i}} \quad \star \quad \mathrm{i} \in L \tag{9}$$

Therefore slack capacity (s_{i}) is always greater than zero for all slack capacity node i is a member of L. So

$$0 < s_{\mathrm{i}} \leq 1 \text{ for all values of slack capacity node } i.$$

Limitation 2: The maximum resource utilization (r_v) is high, where node v is in the set of bi- directional links R.

$$r_v > 0 \star \mathrm{v} \in R \tag{10}$$

The flow rate (p_v) of node v is greater than 0, and the capacity of the node (q_v) is less than or equal to 1. So the maximum resource utilization of node v is less than 1.

3.1 | Resource utilization algorithm (algorithm L-RUBI)

An efficient resource utilization algorithm was presented a bi-directional repetition for multi-hop intervals. The initial step calculates the maximum allocated resource for every interval. The data packets are released according to the allocation of resources. The next step is to dispatch the data packets and schedule it for transfer. All intervals have an equal load, and the supply node of every interval has an unlimited supply of data packets. The reasonable resource utilization is calculated by the pass-key creation process. Every junction produces pass-key for each time interval when packets cross the junction. Whenever the supply node transmits a new packet, it should hold a pass-key. Then the packet allows transmitting; otherwise, it is held by the source node. If the data packet appearance procedure is possible, then the maximum amounts of scheduling have been recognized to reach some possible rate. There are some significant factors can decrease the effectiveness of the poll scheduling in wireless scatternet:

- Slaves have no limits to the data. It caused unwanted polling when all the other slaves are waiting to transfer some important data.
- At the same interval of a predictable poll, one of the slack nodes in a master–slave couple may not appear in the piconet. Then the slave node is being polled is not follow the instructions from the master.

Consider slotted intervals. Node v is a sample of an interval. The nodes r and s be the nearest neighbors of node v. Any node performs immediate up-stream, and another one performs immediate down-stream. All three nodes are bounded in the path of interval i. $A_{i,v}(t)$ is the total number of pass-keys generated in the interval i from the node v at the time interval $(0,t)$. Let node v sample interval i in the period t, then v creates a pass-key for the following:

$$\mathrm{A_{i,v}(t) < \min\left(A_{i,r}(t), A_{i,s}(t)\right) + B} \tag{11}$$

Definition 5. Let r_1, r_2, r_3 ... .r_n be the max–min reasonable rates and $A_{i,v}(t)$ be the number of pass-keys for interval i from the node v at the time interval t. The values of the window factor are always greater than the values depending on the system constraints.

$$\mathrm{B} \geq \mathrm{B_0}\ (\mathrm{B_0}\ \text{is a constant value in every interval}\ (g,h)) \tag{12}$$

$$|A_{\mathrm{i},}(h) - A_{i,v}(g) - r_{\mathrm{i}}(h-g)| \leq \delta \tag{13}$$

where δ is a constant value. Its rates depend on the topology of a scatternet. It is not varying the interval (g, h). Thus, the interval i receives the pass-key unless the number of keys for interval i at node v significantly exceeds to facilitate the nearest neighbors (node r and node s). This excessive variation is a window factor B. The initial and final nodes of an interval have a single neighbor node. Hence, such nodes obtain the pass-key creation choices based on the number of keys at just single nearest neighbor. These keys are never detached from a node. The pass-key creation of complex junctions differs to facilitate the keys on the particular interval. All neighbor nodes lying on the route of the interval varied by B or a reduced amount of any time t.

The deviation is at most HB (H is the amount of hops in the route of a specific interval) for any two nodes on the route of an interval. The amount of key generation of an interval is the same at any two junctions on the route of the interval. The blockage node creates a large amount of congestion. The sampling of a specific interval is the smallest amount at its blockage node, and for this reason, the key generation speed at every node is upper-bounded with this sampling ratio and the key of an interval accurately equals the sampling ratio at its blockage node.

3.2 | Pass-key generation

The samples of every interval pass through the junction v in a round-robin array. Let interval i cross the junction v and nodes r and s are the nearest neighbors to junction v in the particular route of an interval i sampled in the time period t. The pass-key generation process is initiated with the following condition:

$$(A_{i,v}(t) < A_{i,r}(t) + B \;\&\&\; A_{i,v}(t) < A_{i,s}(t) + B) \tag{14}$$

$$\text{The generation of pass} - \text{key for interval } i \text{ at the time}, (A_{i,v}(t+1) = A_{i,v}(t) + 1) \tag{15}$$

If the above conditions are satisfied, then the algorithm generates pass-key or it is not generate any keys for that particular interval i, where

$$(A_{i,v}(t+1) = A_{i,v}(t)) \tag{16}$$

The Algorithm 1 expresses the pass-key generation process. Initially the network performance processing was started. Next the pass-key interval is received as input. Based on these inputs those interval routines are calculated. Pass-key generation is initiated immediately if the value of perhaps A is available. Otherwise, the state of A is raised one block and goes to state A + 1. In this case, the pass-key is transferred to the nearest neighbor. Pass-key generation will stop immediately if no entries are received.

Algorithm 1: Pass-key generation process

Step 1.	***START***
Step 2.	*IF_A* = ($A_{i,v}(t) < A_{i,r}(t) + B \;\&\&\; A_{i,v}(t) < A_{i,s}(t) + B$)
Step 3.	*THEN GEN-PASS-KEY* ($A_{i,v}(t+1) = A_{i,v}(t) + 1$);
Step 4.	*ELSE IF A = A + 1;* (Next Transmit via junction v)
Step 5.	*THEN TRANS_PASS-KEY TO NEIGHBOR;*
Step 6.	*ELSE*
Step 7.	*NOT_GEN_PASS-KEY*($A_{i,v}(t+1) = A_{i,v}(t)$);
Step 8.	*STOP*

Through this security, measures are taken through pass-key. The pass-key generation flow chart was displayed in the flow chart (Figure 2).

3.3 | Scheduling and transmission

Let the junction v live among the nodes r and s. The L_v is the position of the exit of intervals pass through the junction v. $P_{i,r}(t)$, and $P_{i,s}(t)$ are the number of released data packets of interval i to come on nodes r and s at the time t. The load of the junction v is in excess of the limit divergence from node r to node s. Algorithm 2 expresses the scheduling and transmission.

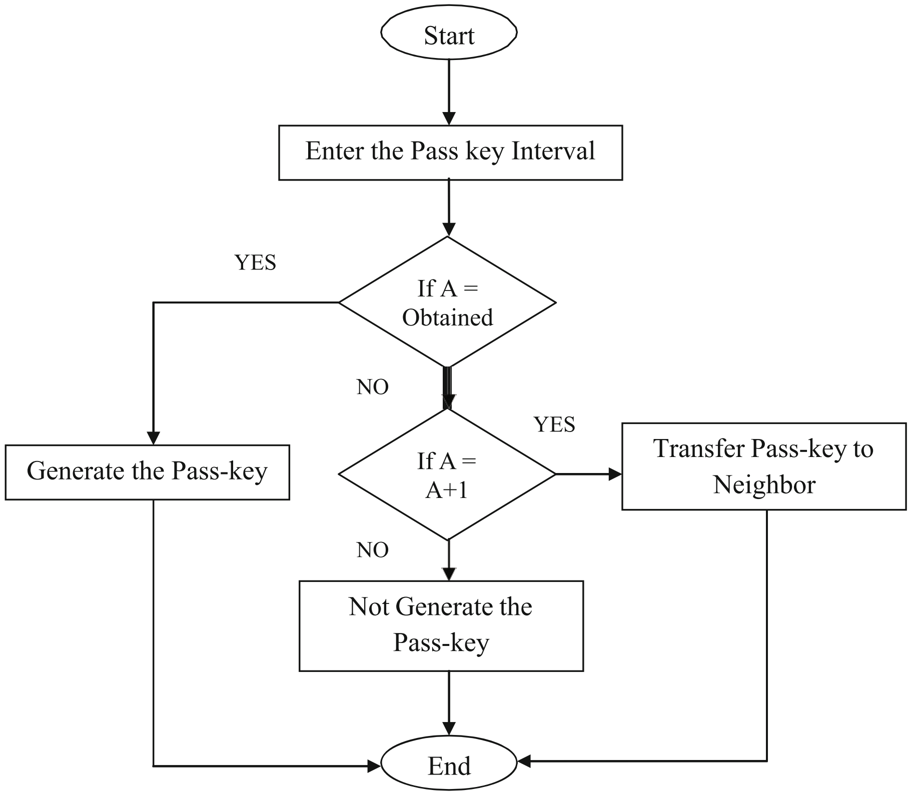

FIGURE 2 Pass-key generation flow chart.

Algorithm 2: Scheduling and transmission

Step 1.	***START***
Step 2.	*INITIATE_SESSION_ i & j*
Step 3.	*CALC_LOAD_SESSION_i* $(L_{i,v}(t)) = max_{i \in Lv}(P_{i,r}(t) - P_{i,s}(t));$
Step 4.	*IF LOAD_v && SESSION_i*
Step 5.	*THEN SCHEDULE_TRANSMISSION*
Step 6.	*ELSE* *CALC_LOAD_ v && SESSION_j* $P_{j,r}(t) - P_{j,s}(t) = max_{i \in Lv}(P_{i,r}(t) - P_{i,s}(t));$
Step 7.	*IF MAX_LOAD_v && SESSION_j* *TRANS_PACKETS (either r or s);*
Step 8.	*ELSE*
Step 9.	*CLOSE_ SESSION_ i & j*
Step 10.	*STOP*

The flow chart of scheduling and transmission was shown in Figure 3. If the load calculated in the junction v for session i, then it is scheduled for transmission or else the session was changed from i to j.

$$L_{i,v}(t) = max_{i \in Lv}(P_{i,r}(t) - P_{i,s}(t)) \tag{17}$$

$$P_{j,r}(t) - P_{j,s}(t) = max_{i \in Lv}(P_{i,r}(t) - P_{i,s}(t)) \tag{18}$$

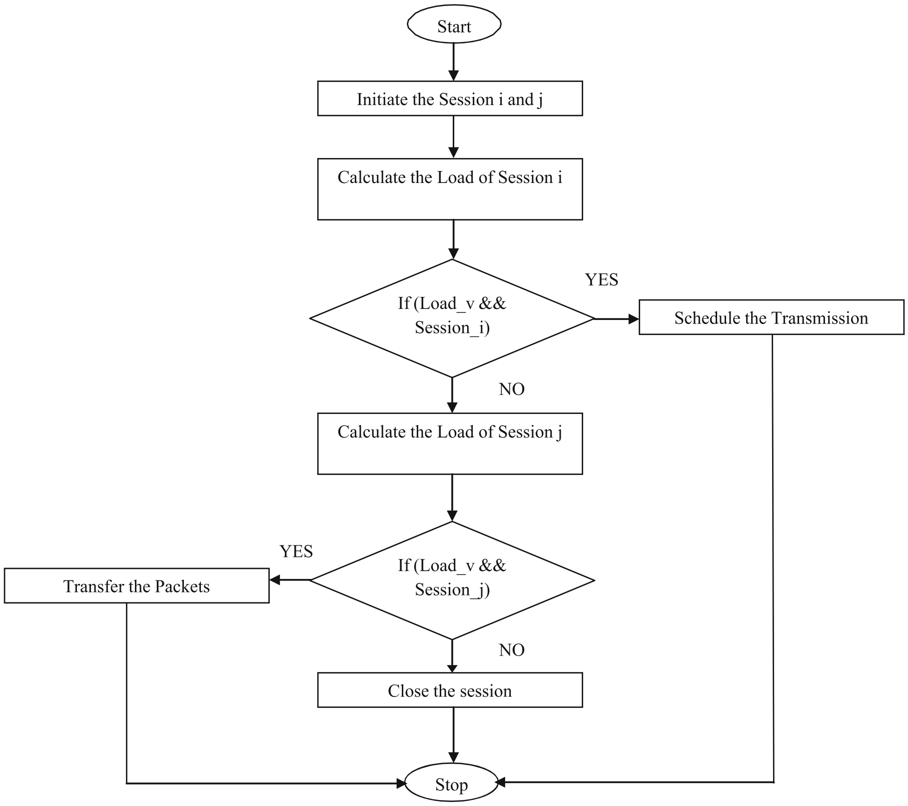

FIGURE 3 Flow chart of scheduling and transmission.

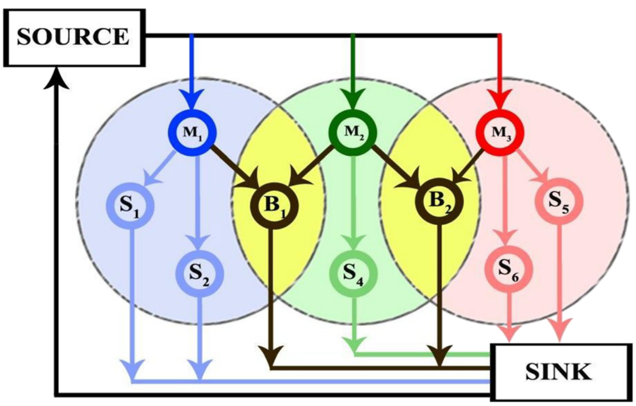

FIGURE 4 Source-sink communication model (M, master; S, slave; B, bipartite nodes).

If the load calculated in the junction v for session j, then data packets are transferred to either the node r or s. First, the work of the network is started. Next, the interval is divided into specific time sessions, and its blocks i and j are calculated. First the load in session i is calculated. Transmissions are made to that block if it is load balanced. These transmissions are done either instantaneously or by scheduling. If perhaps the load does not match, then the load in the next session j is calculated. Now the load and session j are compared according to the previous method. If both are correct, then the message packets are transmitted. If no calculations match, then the session ends.

4 | ANALYTICAL SIMULATIONS

The simulation results are presented based on Figure 4 source-sink communication scatternet model. For the simulation network, Simulator-2 version 2.29 is used. This model scatternet has 10 nodes, which including masters, slaves, and bipartite nodes and 17 different intervals with window factor $(B) = 5$. The max-fair rate is r_i, and the relative divergence among the extended key creation rate is designed for every interval i at the source node ($A_{i,s}(t)$/t). The relative divergence of the node is called *relative error* at time t for the interval i.

$$\text{Relative error } (R_e) = |1 - \frac{i,s(t)}{\text{ri}(t)}| \quad (19)$$

Definition 6. If the reasonable resource allocation for N-dimensional vector with positive real numbers (r_1, r_2 ... . r_n), then the intervals can be listed for data transfer such that interval (i) attains resource (r_i) for every i. There are two sample sessions with different nodes between sources to sink calculated,

Session 1: (M1, S1), (M1, S2), (M2, S4), (M3, S5) and (M3, S6).
Session 2: (M1, B1), (M2, B1), (M2, B2), and (M3, B2).

Figure 5 demonstrates the ratio between the maximum relative error and average error for all intervals at the time t. The convergence of the pass-key generation ratio to the max–min reasonable rates, if all the sessions with different flooded intervals, then the max–min resource utilizations are (0.43, 0.43, 0.6, 0.6, 0.35, 0.35, 0.25, 0.25, 0.45, 0.45, 0.43, 1.2, 1.2, and 1.2).

If the initial session is started (M1, S1) to receive data packets at 0.1 for each unit time t, then further sessions are flooded. The max–min resource allocation is (0.18, 0.35, 0.35, 0.35, 0.20, 0.20, 0.20, 0.20, 0.55, 0.55, 0.45, 1.10, 1.10, and 1.10).

The following information is obtained from the observation of the above results.

- The average relative error grows moldy fast. It is less than 10% with in1000 slot intervals.
- The maximum relative errors grow moldy rather slower point out for some intervals experience slower junction.
- The key generation rate at a junction obtained maximum rates even the window factor (B) = 5 and it is verified by the network admin with various network topologies.

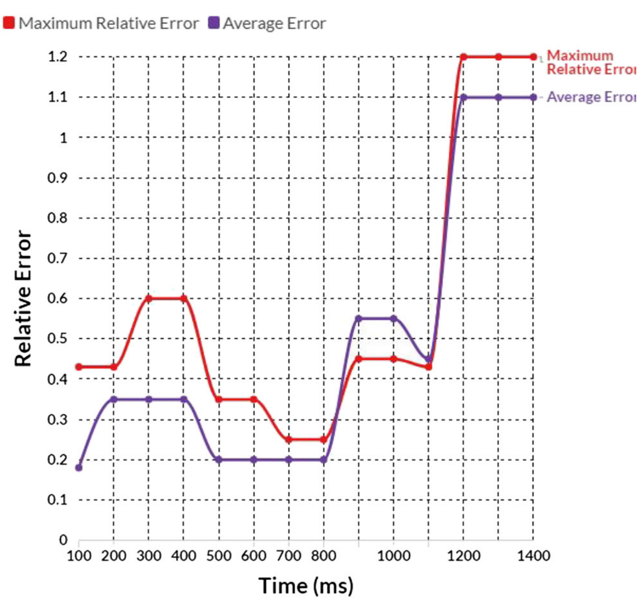

FIGURE 5 Pass-key generation for all intervals.

- The pass-key generation speed instantly reached the max–min reasonable bandwidth on an average time interval.
- All observed junctions are not responsive to the selection of window factor (B) as well as reasonable standards of window factor (B) in the choice of 5 to 10 guaranteed junctions. Thus, a little window size can be used to manage various requirements (packet delay and buffering).

5 | COMPARATIVE ANALYSIS

The performance parameters of the proposed L-RUBI model was compared with the existing load adaptive scheduling algorithm (LASA) and pseudo random coordinated scheduling scheme (PCSS). In this comparison, the reliability, throughput, collision probability, transmission probability, and signal-to-noise interference ratio are taken as performance parameters. In relation to that, the simulation parameters are listed in Table 2,

5.1 | Measurement of reliability

To define the network reliability $N(r)$, we must first define the connectivity of nodes in the network. Network reliability is defined as the probability that a source node is out of touch with other nodes in the network. Here the link failure probability is p. Figure 6 demonstrates the reliability comparison between the existing LASA, PCSS methods, and proposed L-RUBI. Here the x-axis indicates the number of nodes available in the network, and the y-axis illustrates the

TABLE 2 Simulation parameter

Parameter	Value
Area estimated for simulation	1000 × 1000 m
Short inter-frame space (SIFS)	26 s
Transmission data rate	10 Mbps
Interference detection rate	30 ms
slot time	8 ms
Sub-channel bandwidth	710 GHz
System bandwidth	20 MHz
Carrier frequency	10.3 MHz
Simulation time	39 s

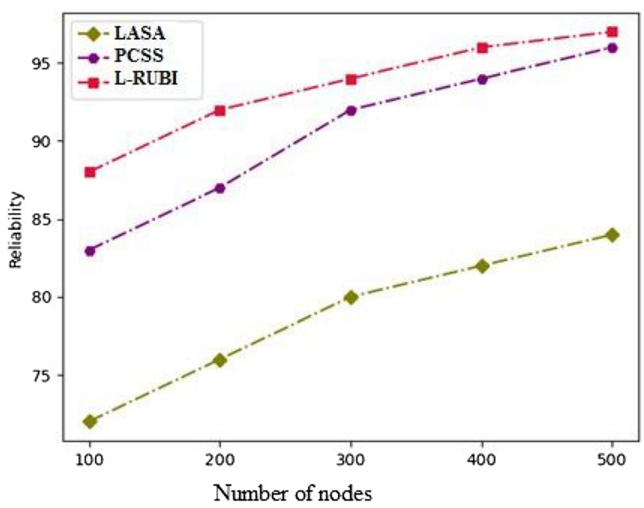

FIGURE 6 Comparison of reliability.

amount of reliability in percentage. In the graph, green color indicates the LASA model, violet color is the PCSS model, and the green one is the L-RUBI model.

While the performance is analyzed on the basis of reliability measurements on the saturation tip, the existing LASA model achieved 78.8%, and the PCSS model reached 90.4%. But the proposed L-RUBI model obtained 93.6% of reliability measurements. While comparing the existing results, the proposed L-RUBI model is 14.8% better than LASA and is 3.2% better than PCSS because the pass-key-based entry provides the highly secured entry. Here the unauthorized users are unable to enter the network. If the illegal entry has arrived, then the load was not balanced by the session. If the session was not balanced, then the transmission was not initiated. So resource wastage is not available in the network, thus, the reason to increase the reliability.

5.2 | Measurement of transmission probability

The transmission probability is the performance parameter when the load was balanced with the particular session, then the transmission was initiated. The transmission probability provides clear details of the ratio to initiate the transmission while all the authorized users are available in the network at the particular session. Figure 7 demonstrates the transmission probability comparison between the existing LASA, PCSS methods, and proposed L-RUBI. Here the *x*-axis indicates the number of nodes available in the network, and the *y*-axis illustrates the amount of transmission probability in percentage. In the graph, the green color indicates the LASA model, violet color is the PCSS model, and the green one is the L-RUBI model.

While the performance analysis is analyzed on the basis of transmission probability measurements on the saturation tip, the existing LASA model achieved 81.8% and PCSS model reached 92.2%. But the proposed L-RUBI model obtained 95.7% of transmission probability measurements. While comparing the existing results, the proposed L-RUBI model is 13.9% better than LASA and is 3.5% better than PCSS. The load played a major role in the transmission. In the particular session, the matching load priority was high because the proposed model provides the authenticated user to utilize the resource in the particular session. Hence, the proposed model gets high transmission probability.

5.3 | Measurement of throughput

It is the rate at which platoon members reach their target successfully within a specific time. Let T_i denote the time to calculate the throughput of platoon members in one platoon. Let x_{ij} denote channel assignment decision where $x_{ij} = 1$. Then, the issue in maximum output can be represented in equation (20).

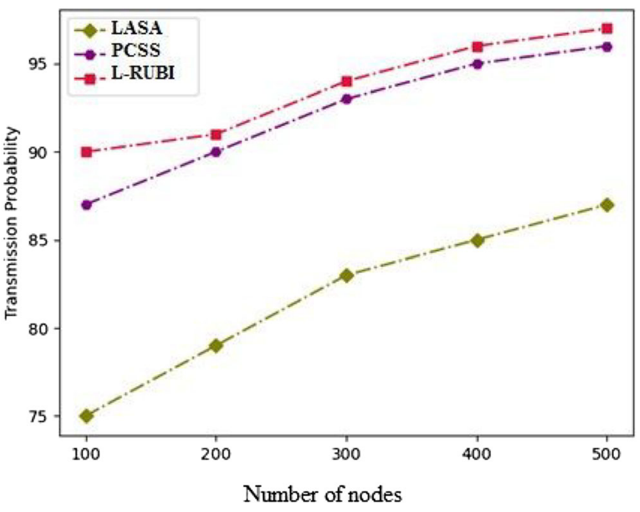

FIGURE 7 Comparison of transmission probability.

$$xij = \max\sum\nolimits_{i=l}^{m} \mathrm{xij} = max\sum\nolimits_{\mathrm{i}=1}^{m} T_{\mathrm{i}} \tag{20}$$

Figure 8 demonstrates the throughput comparison between the existing LASA, PCSS methods, and proposed L-RUBI. Here the *x*-axis indicates the number of nodes available in the network, and the *y*-axis illustrates the amount of throughput in percentage. In the graph, green color indicates the LASA model, violet color is the PCSS model and the green one is the L-RUBI model.

While the performance is analyzed on the basis of throughput measurements on the saturation tip, the existing LASA model achieved 76.2%, and PCSS model reached 81.2%. But the proposed L-RUBI model obtained 91.6% of throughput measurements. While comparing the existing results, the proposed L-RUBI model is 15.4% better than LASA and is 10.4% better than PCSS. When the reliable transmission was increased, then the throughput also increased because the reliable users efficiently utilize the resource. Hence, the proposed L-RUBI model achieved better results when compared with the other existing methods.

5.4 | Measurement of collision performance

When the platoon member communicates with one in the same platoon with probability a and collision probability p_s, and $1 - a$ is the probability of communication in another platoon, and the collision probability p_o, the final collision probability Pc is given as

$$\mathrm{Pc} = \mathrm{a}^* \, \mathrm{p_s} + (1 - \mathrm{a})\mathrm{p_o} \tag{21}$$

Figure 9 demonstrates the collision performance comparison between the existing LASA, PCSS methods, and proposed L-RUBI. Here the *x*-axis indicates the number of nodes available in the network and the y-axis illustrates the amount of collision performance in percentage. In graph, green color indicates the LASA model, violet color is the PCSS model, and the green is the L-RUBI model.

While the performance is analyzed on the basis of throughput measurements on the saturation tip, the existing LASA model achieved 88.6%, and PCSS model reached 85.8%. But the proposed L-RUBI model obtained 78.6% of collision performance measurements. While comparing the existing results, the proposed L-RUBI model is 10% better than LASA and is 7.2% better than PCSS. The proposed model achieved better performance results against the collision because the number of reliable users in the particular session provides equal resource allocation. If the number of authorized users is huge, then the resource allocation was equally distributed between the users.

The overall performance analysis was demonstrated in Table 3. When compared with the existing methods, the proposed L-RUBI model increased the reliability from 3.2% to 14.8%, transmission probability from 3.5% to 13.9%, and

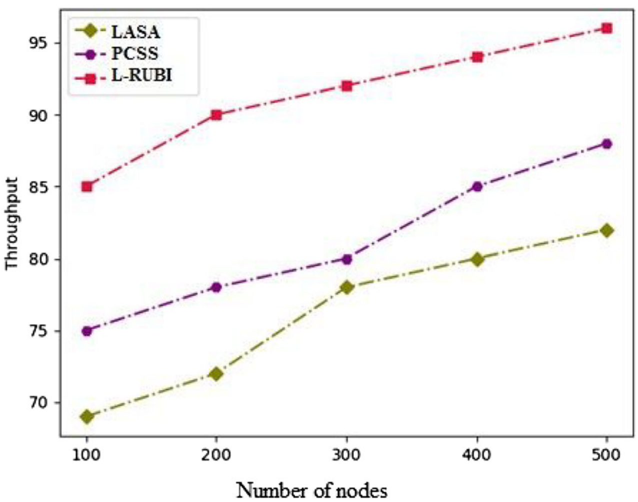

FIGURE 8 Comparison of throughput.

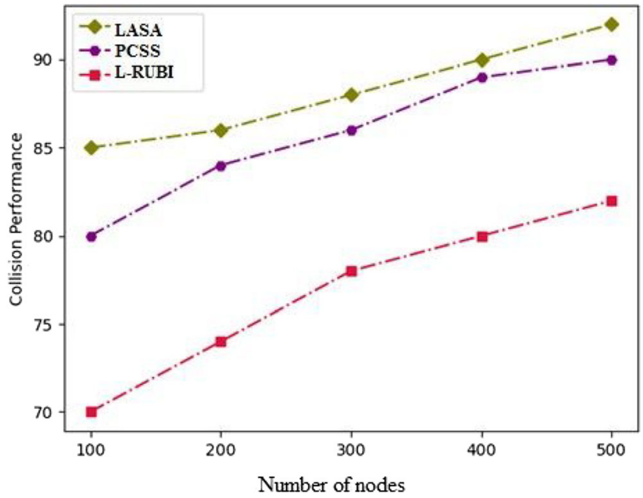

FIGURE 9 Comparison collision performance.

TABLE 3 Overall comparative analysis

Parameters	LASA (%)	PCSS (%)]	L-RUBI (%)
Reliability	78.8	90.4	93.6
Transmission probability	81.8	92.2	95.7
Throughput	76.2	81.2	91.6
Collision performance	88.2	85.8	78.6

throughput from 10.4% to 15.4%. The collision was reduced from 7.2% to 10%. The authorized entry based on the pass-key and the reliable transmissions are the major reasons to boost the performance of the proposed model.

6 | CONCLUSIONS

The calculation of the load-based resource utilization and the scheduling are able to function equivalently. Both pass-key generation and message packet scheduling are performed in parallel operations. This sequential process enhances the overall delay to achieve the preferred bandwidth allocation. The L-RUBI algorithm boosts the performance of the slack node based on schedule, and then the whole delay was reduced. This algorithm does not require regenerating if fresh intervals link or existing intervals are left. The implementation of the key generation and the data packet discharge works are not closely joined to this specific scheduling. It is found that the proposed L-RUBI achieves 93.4% of reliability, 93.6% of transmission probability, 91.4%of throughput, 76.8% of collision performance, and 72.2% signal-to-noise ratio (SINR). As a result, future research works will be focused on the exploration of centralized and distributed scheduling, and this approach preserves the conjunction. The logical scheduling assured constant performances in this active situation. The performance of the node should assure hold, yet junctions recognize the total amount of keys at its adjacent nodes. The transmission is just next to a prior time direct, as long as the time interval is highly restricted. A junction can perform the key generation and the data packet discharge methods through the information of its single adjacent node. In the future, efforts will be made to increase the detection speed of curve allocation methods to make them more efficient, and as the session size and its users are regulated, the chances of this method handling more users increases.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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