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Performance Measurement of Throughput Enhanced Wireless in Local Loop Architecture Using Markov Chain Process

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***Abstract*— In the existing Throughput enhanced Wireless in Local Loop (TWiLL) system, the Packet Acceptance Ratio obtained for various parameters is very low. The Packet Acceptance Ratio vs Node Density decreases from 0.8 to 0.4 with increase in number of nodes, the Packet Acceptance Ratio vs number of channels increases from 0 to 0.5 with increase in number of channels and the Packet Acceptance Ratio vs. Locality decreases from 1 to 0.3 with increase in locality. The number of subscribers in Wireless Networks such as Throughput enhanced Wireless in Local Loop (TWiLL) is increasing, thereby it becomes beneficial to use spectrum reusability techniques to utilize the bandwidth. To improve the capability of TWiLL systems, multi-hop relaying is used. The technological challenges faced by the existing system are its performance output obtained by analyzing the Packet Acceptance Ratio vs Node density, Packet Acceptance Ratio vs number of channels and Packet Acceptance ratio vs locality of existing TWiLL system is less as compared to that of the proposed TWiLL system. The research focuses on designing a TWiLL system with a Packet Acceptance Ratio vs Node density of 0.9 (increase in 0.2) and Packet Acceptance Ratio vs number of channels of 0.3 (increase in 0.05) and Packet Acceptance ratio vs locality of 0.9 (increase in 0.09).**

***Keywords*— Continuous Time Markov Chains, Discrete Time Markov Chains, Multi-hop relaying, Packet Acceptance Ratio, Single hop relaying.**

I. INTRODUCTION

A Throughput Enhanced Wireless in Local Loop (TWiLL) Architecture is as shown in Fig 1. It consists of a cell which are divided into various clusters. Each cluster consists of various nodes or Fixed Subscribers Unit (FSU). An FSU is an equipment which is used for communication with the Base Transceiver Station (BTS).[1] A Base Transceiver Station or a base-station is located at the center of a cell. A BTS communicates with the nodes or FSU over the wireless link and PSTN over a wired link.

A TWiLL system offers many advantages over a Wireless in local Loop (WiLL) system like it uses multi-hop relaying and single hop relaying to reuse system bandwidth.

If the amount of subscribers or FSUs are increased, the electromagnetic spectrum's capacity remains the same and as a result the number of subscribers that can be simultaneously served is limited. This limitation offered by WiLL system can be overcome by using TWiLL system.[2]

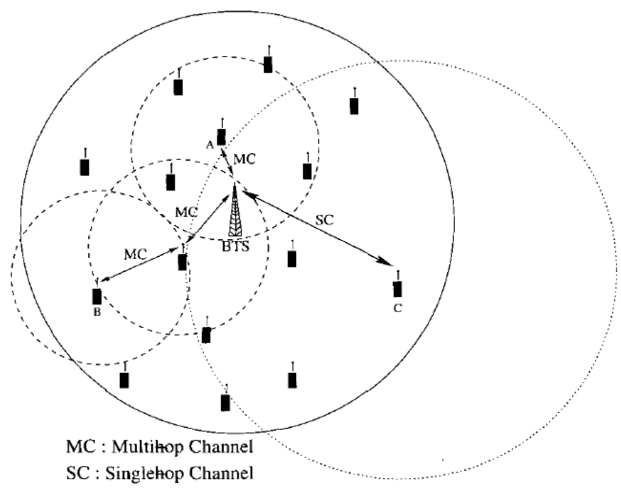

Fig 1 : TWiLL Architecture.

The layout of the paper is as follows. Section 2 describes about Markov Chains, Section 3 states about the Problem Definition, Section 4 describes about the System Architecture, Section 5 explains about the Packet Acceptance Ratio, Section 6 shows the Simulation Results and Section 7 states the Conclusion of the paper.

II. MARKOV CHAINS

A Markov process is named after Andrey Markov, a Russian mathematician. It can be defined as a stochastic process that fulfills the Markov property. A stochastic process has Markov property if the future states of the process depend only upon the present state, and not on the past states i.e. the sequence of events that preceded it. A Markov chain is a type of Markov process that has either discrete time state space or continuous time state space.[3]

A Markov Chain can thus be defined as Sequence of stochastic events (based on probabilities instead of certainties) where the current state of a variable or system is independent of all past states, except the current (present) state. Examples of Markov Chains include movements of stock/share prices, and rise or fall in a firm's market share.[4]

Fig 2 shows a two state markov process. The two states are named E and A. The arrows indicate the direction in which the state changes from one state to another and the numbers associated with it indicate the probability of transition.

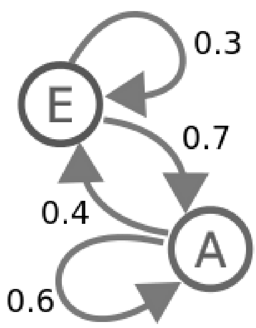

Fig 2: Two state Markov process

From Fig 2. It can be seen that the probability of transition from state E to A is 0.7 and that from state A to E is 0.4. Similarly the probability of transition from E to itself is 0.3 and that from A to itself is 0.6. Markov Chain can further be classified as Discrete Time Markov Chain and Continuous Time Markov Chain.

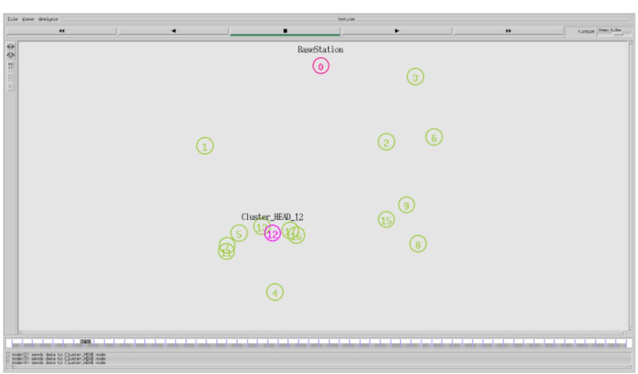

Fig 3: Nodes with Discrete type Markov Chains

The figure above shows a TWiLL network using Discrete Markov Chain. In this system the network consists of a single cluster with a single access point known as a cluster head which communicates with the base station.

The nodes individually or discretely communicate with the access point which in turn communicates with the base station.

In discrete-time Markov chain the system changes at discrete time intervals. So changes to the system can only happen at one of the discrete time values. A discrete time stochastic process $\{X_n, n = 0, 1, 2, ...\}$ with discrete state space is a Markov chain if it satisfies the Markov property.

$$P(X_n = i_n / X_0 = i_0, X_1 = i_1, ..., X_{n-1} = i_{n-1}) = P(X_n = i_n / X_{n-1} = i_{n-1}) \quad (1)$$

where i_k for all k = 0, 1, ..., n are realized states of the stochastic process.

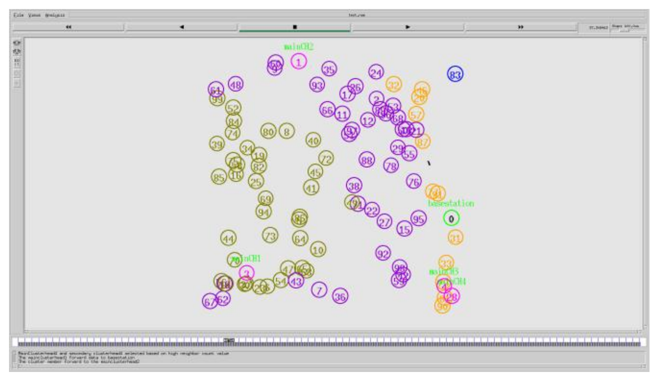

Fig 4: Nodes with Continuous type Markov Chains

The figure above shows a TWiLL network with continuous markov chain. This system consists of network with many clusters and many access points. The nodes from a cluster communicate with its access point which in turn communicates with the basestation which further communicates with other nodes in the different cluster forming a continuous chain of communication

A continuous-time Markov chain is one in which changes to the system can happen at any time along a continuous interval. A continuous-time stochastic process, $(X(t))_{t\geq0}$, with state space E is a collection of random variables X(t) with values in E. With an at most countable state space, E, the distribution of the stochastic process, $(X(t))_{t\geq0}$, is determined by the probabilities

$$P\{X(t_0) = i_0, X(t_1) = i_1, . . ., X(t_n) = i_n\} \quad (2)$$

For $0 \leq t_0 < t_1 < . . . < t_n$, $i_0, i_1, . . ., i_n \in E$ for all $n \in N$.

III. Problem Definition

- To design a TWiLL Network with 50 - 100 nodes, spread over a terrain of dimensions 500 m x 500 m.

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- To implement Cluster Formation and Cluster Head Selection, a master node is selected in each cluster and rest of the nodes are taken as slave.
- To calculate the Packet Acceptance Ratio vs Node Density by varying the Node Density between 50 – 100 nodes, the Mean Call Holding Time is fixed at 20 sec and Mean Inter Call Arrival Time is fixed at 10 sec.
- To calculate the Packet Acceptance Ratio vs Number of Channels by varying the number of channels simultaneously used between 0 – 10.
- To calculate the Packet Acceptance Ratio vs Locality by varying the locality from 0 to 1.

IV. System Architecture

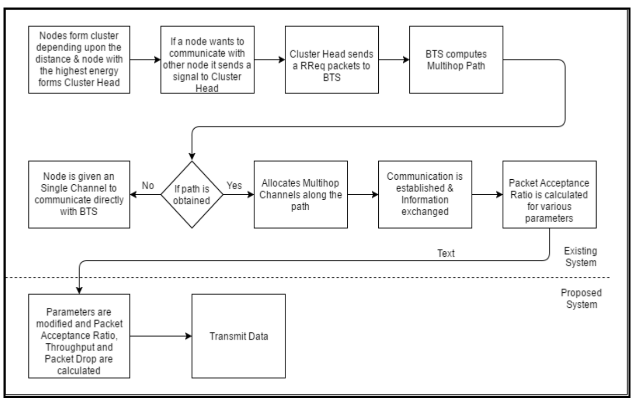

Fig 5 : The System Architecture and flowchart

The System Architecture and flowchart is as shown in Fig 5.

Existing System

- A cluster of nodes is formed depending upon the distance and the node with the highest energy becomes the Cluster Head.
- If a node wants to communicate with the other node from a different cluster it sends a signal to the Cluster Head
- Cluster Head sends R_{Req} packets to the BTS.
- BTS computes multi-hop path.
- If a path is not obtained, a node is given a single channel to communicate directly with the BTS.
- If a path is obtained, it allocates multi-hop path along the path.
- Communication is established and information is exchanged in the network
- The Packet Acceptance Ratio is calculated for various parameters like Node density, number of channels and locality.

Proposed System

- Parameters of Node Density, number of channels and locality are modified and values for Packet Acceptance Ratio, Throughput and Packet Drop are calculated.
- Information is transmitted and communication established

V. Packet Acceptance Ratio

Packet Acceptance ratio can be defined as the ratio of the number of packets successfully delivered to the destination node upon the total number of packets sent by the sender node.[5]

Packet Acceptance Ratio = No. of packets successfully delivered / Total no. of packets sent

VI. Simulation Results

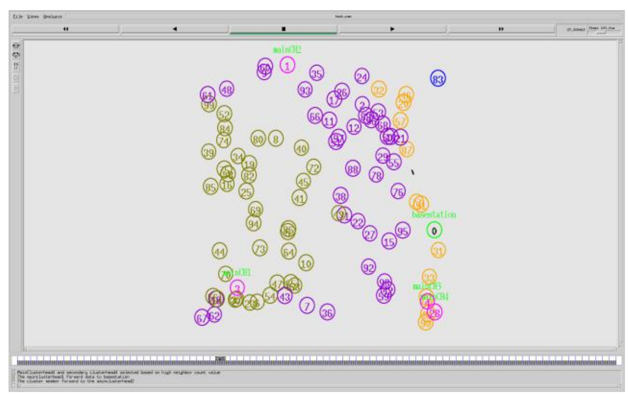

Fig 6: Simulation of 100 nodes with Network Simulator 2

To evaluate the performance of the TWiLL system, a network with 50 - 100 nodes is simulated in Network Simulator 2. The communication between the various nodes is analyzed and the Throughput, Packet Acceptance Ratio and Packet Drop of the network is measured in the system. In the graphs calculated below, the green segment represents the data values of existing system and the red segment represents the data values of proposed system.

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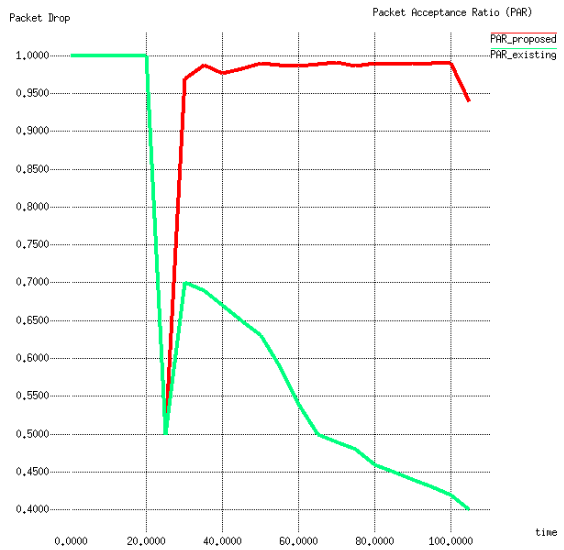

Fig.7 : Graph of Packet Accceptance Ratio vs Node Density

In Fig.7, the graph of Packet Acceptance Ratio vs Node Density of the network is shown. It can be seen from the graph that the packet acceptance ratio of proposed system is low when the calling starts at 26 sec but then it increases and remains constant at around 1 with increase in time till 65 sec when it drops down to 0.86 and further at 105 sec drops down to 0.82 sec. The Packet Acceptance Ratio of existing system goes up to 0.5 and then drops down to 0.3. The minimum packet acceptance ratio achieved is 0.5 and maximum achieved is 0.99.

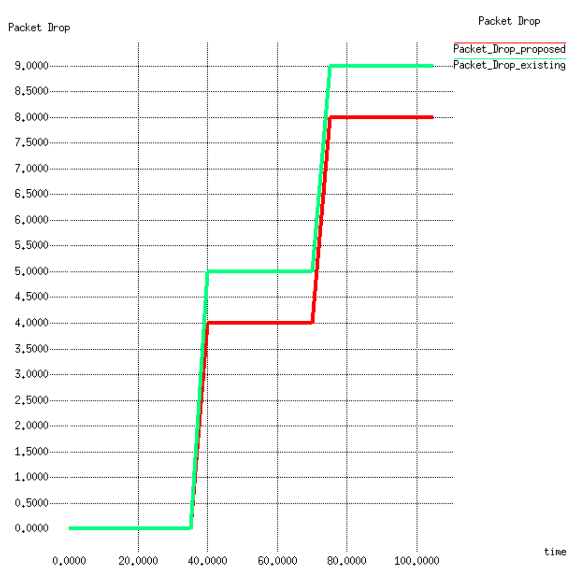

Fig.8 : Graph of Packet Drop vs Node Density

Fig.8 shows a graph of Packet drop vs Node Density in the network. It can be seen from the graph that there is no packet drop in the initial stages but later the packet drop increases. The packet drop is 0 till 38 sec, it gradually increases to 4 bps till 70 sec and it increases to 8 bps till 110 sec. The Packet Drop of existing system rises from 5 bps to 9 bps.

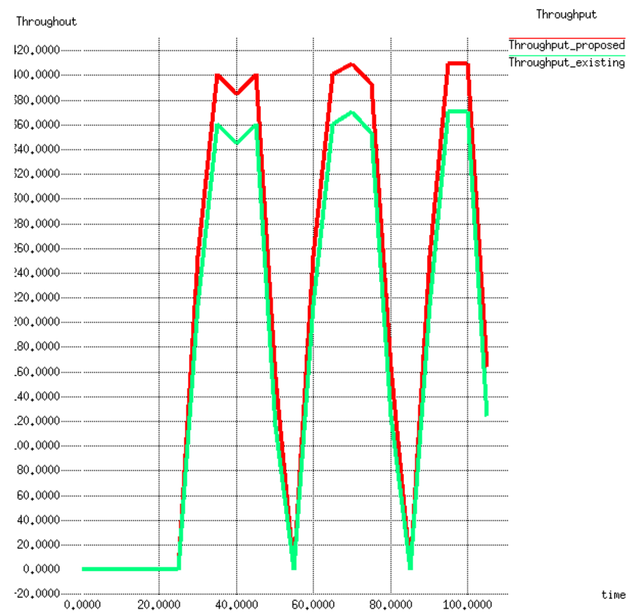

Fig.9 : Graph of Throughput vs Node Density

Fig.9 shows a graph of Throughput vs Node Density in the network. It can be seen from the graph that there is no throughput till 26 sec. But when the calling starts after 26 sec the throughput increases to 400 bps and then it drops down to 0 after 45 sec at end of first call. It again goes up to 400 bps at 65 sec and it varies between 160 bps to 240 kbps and it drops down back to 0 at the end of second call. The throughput of existing system rises to 370 bps.

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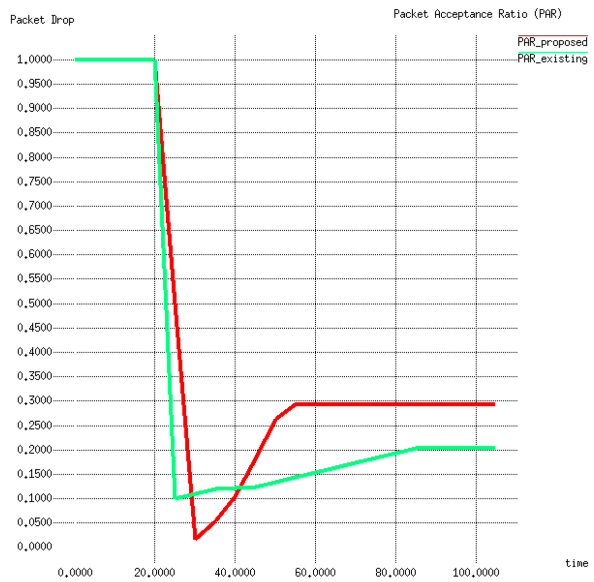

Fig.10 : Graph of Packet Acceptance Ratio vs Number of Channels

In Fig.10, the graph of Packet Acceptance Ratio vs Number of Channels is shown. It can be seen from the graph that the packet acceptance ratio of the proposed system is low when the calling starts at 26 sec but then it increases and remains constant at around 0.3 with increase in time for various number of channels between 0 - 10. The Packet Acceptance Ratio of existing system increases from 0.1 to 0.25. The minimum packet acceptance ratio achieved is 0 and maximum achieved is 0.3.

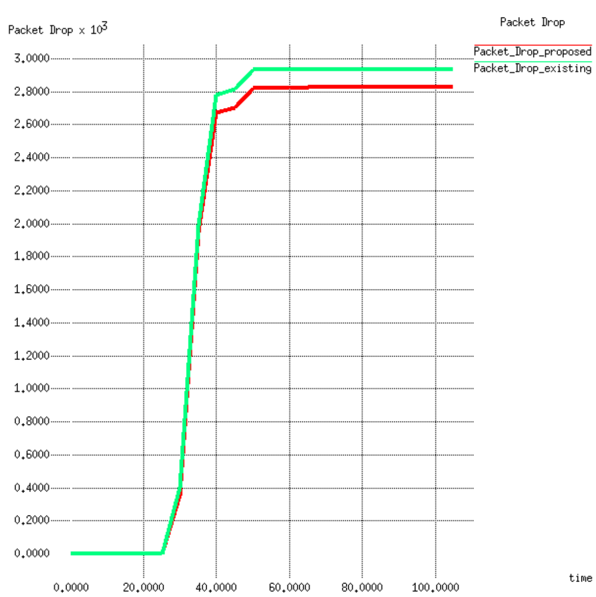

Fig. 11 : Graph of Packet Drop vs Number of Channels

Fig.11 shows a graph of Packet drop vs Number of Channels in the network. It can be seen from the graph that there is no packet drop in the initial stages but later the packet drop increases. The packet drop is 0 till 25 sec, it gradually increases to 2.8 kbps till 105 sec. The Packet Drop of existing system rises to 2.9 kbps.

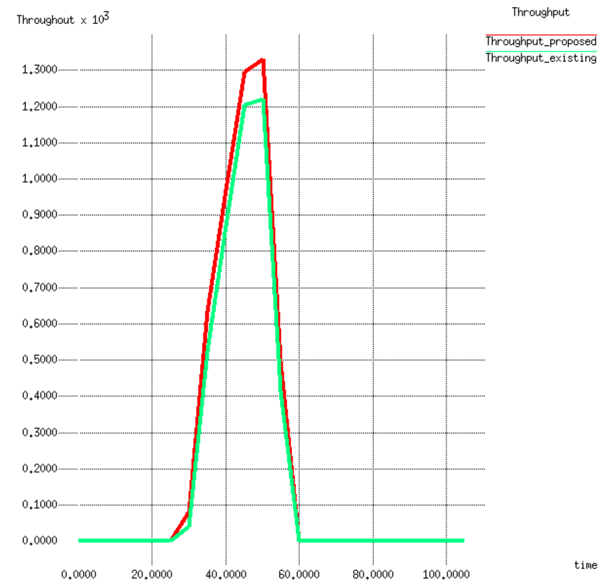

Fig. 12 : Graph of Throughput vs Number of Channels

Fig. 12 shows a graph of Throughput vs Number of Channels in the network. It can be seen from the graph that there is no throughput till 26 sec. But when the calling starts after 26 sec the throughput increases to 1.35 kbps till 50 sec and then again drop down to 0 at 60 sec. The throughput of existing system to 1.2 kbps.

In Fig.13, the graph of Packet Acceptance Ratio vs Locality is shown. It can be seen from the graph that the packet acceptance ratio of proposed system is low when the calling starts at 26 sec but then it increases to 0.9 and again drops to 0.6 and then keeps on varying between 0.72 and 0.82 with increase in time for locality between 0 - 1. Even if the nodes have moved from one cluster to another, the packet acceptance ratio varies constantly with change in locality. The Packet Acceptance Ratio of existing system decreases from 0.9 to 0.5. The minimum packet acceptance ratio achieved is 0.5 and maximum achieved is 0.9.

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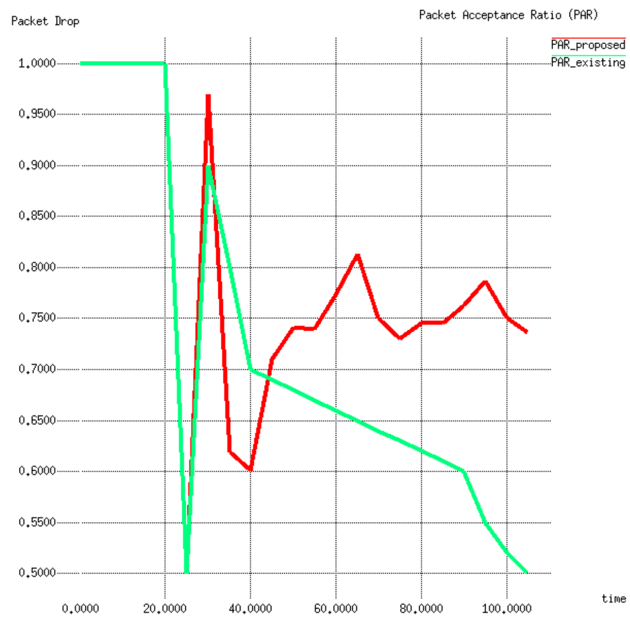

Fig.13: Graph of Packet Acceptance Ratio vs Locality

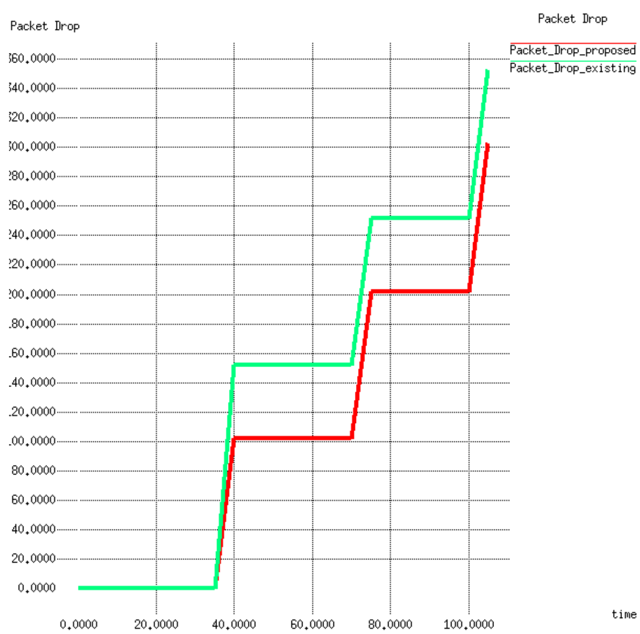

Fig 14: Graph of Packet Drop vs Locality

Fig.14 shows a graph of Packet drop vs Locality in the network. It can be seen from the graph that there is no packet drop in the initial stages but later the packet drop increases. The packet drop is 0 till 35 sec, it gradually increases to 100 bps till 70 sec and it increases to 200 bps till 100 sec. The Packet Drop of existing system rises from 150 bps to 250 bps to 350 bps.

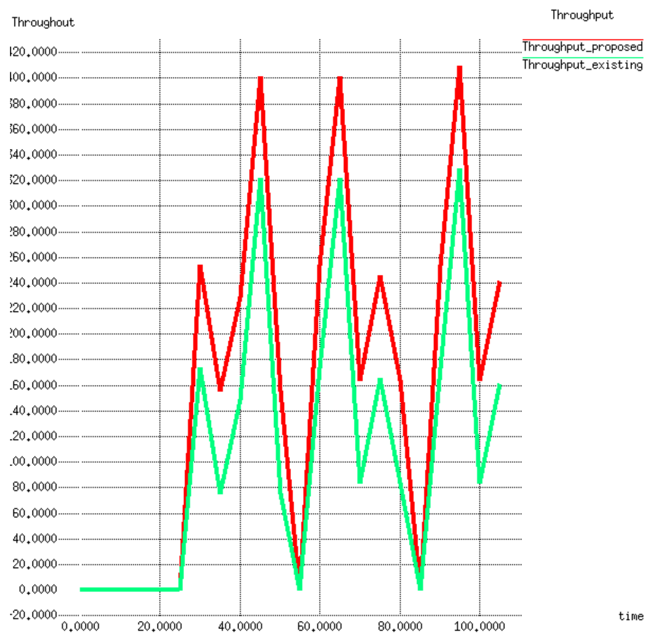

Fig 15: Graph of Throughput vs Locality

Fig. 15 shows a graph of Throughput vs Locality in the network. It can be seen from the graph that there is no throughput till 26 sec. But when the calling starts after 26 sec the throughput varies between 160 bps and 400 bps till 50 sec after which it drops down to 0. After 50 sec at end of first call, it again varies between 400 bps and 160 bps till 80 sec and then drops down to 0 at the end of second call. Similarly for the third call after 85 sec, it varies between 160 bps to 400 bps and it drops down back to 0 at the end of third call. The Throughput of existing system goes up to 320 bps.

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TABLE I
RESULT SUMMARY

Parameter	Results Reported			Results Achieved			Difference between Results Achieved & Results Reported		
	Packet Acceptance Ratio (PAR)	Packet Drop	Throughput	Packet Acceptance Ratio (PAR)	Packet Drop	Throughput	Packet Acceptance Ratio (PAR)	Packet Drop	Throughput
Node Density	0.7	9	370	0.99	8	400	0.29	-1	30
Number of channels	0.25	2900	1200	0.3	2800	1350	0.05	-100	150
Locality	0.9	350	320	0.99	200	400	0.09	-150	80

VII. CONCLUSION

Multi-hop relaying results in significant bandwidth reuse in WiLL architecture and therefore TWiLL system performs steadily better than the traditional WiLL systems. It is observed that the TWiLL architecture provides a maximum throughput of 400 kbps, Packet Drop of 2800 bps and Packet Acceptance Ratio of 0.99. We have validated our analysis with experimental values from simulations and thus verified the correctness of our model.

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