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Original Article

Improved Resource Scheduler using Kalman Filter in Wireless Communication

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Abstract - *Adaptive resource allocation is a major part of the current wireless communication system. Resource allocation in Communication means data rate allocation, Power allocation, Bandwidth allocation and so on to the user. Resource Allocation controls the offered service and dynamically supports multiple resources based on the traffic model, service demand and mode of communication. The optimal allocation of resources offers maximization of system performance and less resource wastage. If all the users in the network communicate with the maximum data rate, there is a probability of high collision in the channel. Based on the volume of the data exchanged over the channel, interference may be effective; hence, to overcome this, resource or data rate or bandwidth is allocated based on the interference. The current filtration-based approach shows a significant improvement in data accuracy and delays minimization. However, dynamic interference due to channel variation is not considered. The time-variant nature of the channel has a greater impact on the allocation of resources. Hence, a new allocation approach based on the Kalman filter with interference governance is proposed. The presented approach, called Improved Kalman Control, is the controlling of data rate under multiple users scenario and illustrates an improvement in the system performance under dynamic channel conditions.*

Keywords - *Improved resource scheduler, Kalman filter, Wireless communication, Resource allocation.*

1. Introduction

The emerging technology has driven the conventional wireless communication system towards digital networks to provide better services with respect to accuracy and speed of data exchange. With the evolution of new technologies in communication, multiple user data are exchanged over the wireless channel simultaneously. Multiple services are also being added to the existing systems, which are constrained by available resources.

The demand for new services such as video streaming, Multimedia services, IP services, live conferencing etc., has a large bandwidth requirement which constrains the compatibility of demanded service in current communication devices. The increase in data rate solves the issue of service compatibility; however, the increase in the transmission data rate has a greater impact on the end-to-end error in transmission. Higher interference is observed in the propagating channel as it is dynamic in nature. This demands a complex approach to computing in signal estimation. The existing approaches are proposed for dynamic resource allocation, where the data rate is controlled by monitoring parameters, and allocation is developed based on a complex computing approach to information under dynamic propagation conditions. The limited available resource and the dynamic channel conditions reflect a dual bottleneck in designing the new resource monitoring and estimation approach.

To make the communication system efficient at remote usage, the current approach must be enhanced and modified to reduce resource wastage and provide efficient performance. Towards the development of optimal resource allocation, in [1], an interference-monitored resource allocation algorithm based on a load-balancing approach is presented. The approach process a multidimensional coding where the base stations are defined with minimum information on the streaming packet and the allocated bandwidth in use. [2] presents an adaptive resource allocation of optimal usage of the communicating protocol, which refers to aggregated packet loss minimization. A scalable power and data rate allocation approach is outlined in [3]. This approach proposed a distinct power allocation method in a cross-layer for coding and communication power. In [4], a streaming operation with respect to Interference monitoring is presented. This approach develops channel interference coding based on temporal and spatial service quality. In [5], a scalar quantization based on scalable encoding operation is presented. The outlined approach presented a variable bandwidth allocation over a nonlinear channel condition. In allocating resources for wireless communication in [6] adaptive data, streaming is used, which also controls the bandwidth allocation with the user's mobility. In [7,8], an application for high-rate service offering a multimedia interface is outlined. This developed an approach to minimizing error under transmission. A delay-tolerant approach for the multi-user interface is developed for delay minimisation in wireless transmission. In [9], an optimal real-time interface for rate control in transmission control protocol is presented. The interface of TCP optimizes the approach to exchange packets for transmission. A Forwarded Error Correction (FEC) for packet loss control in a dynamic network environment is outlined in [10]. A customized approach of varying bandwidth is presented for streaming packets following random packet loss in the dynamic channel environment. A scalable multi-hop communication with a dynamic data rate interface is outlined in [11]. Control of data rate following a congested network model under variant interference conditions is outlined in [12]. A forward error correction and re-correction by transmission code allocation are presented here. A fine-tuning approach to the data rate in error-free coding using forward error correction (FEC) is outlined. For heterogeneous networks, the resolution of transmission data, frame rate and error-controlling communication for code allocation with bitstream controlling is presented in [12]. In [25], the problem of scalable data broadcast is presented. In [14, 15], a low-power wireless network for transmission through a new framework is proposed for the selection of multiple accessing channels for communication. In [16], the wireless Physical Layer (PHY) rate is encoded and combined for source and cross-layer optimization in wireless LAN. These are used for transmitting the data packet over a wireless channel in an adaptive manner.

In [17], a rate control mechanism following optimal data rate coding for packet loss is outlined. The outlined approach controls the transmission rate based on predicted channel interference and outlines a new control of data rate based on packet loss monitored. In [26], error correction coding using FEC is integrated with rate allocation in the application layer. The proposed approach is outlined as a joint source-channel coding for interference mitigation. In the control of resource allocation in [19], a data rate control for error rate controlling and signaling conditions is developed under dynamic frequency channel interference. The channel estimation is performed for interference mitigation with dynamic rate allocation to achieve higher throughput and lower interference levels. In this, an important adjustment scheme in the layer switching for the flow is presented. It adapts to faster data switching than a simple scheduler to improve the quality of the data exchange in the sense of R-D under bandwidth limitation.

A completely randomized framework for the optimal encoding of data over a distorted network which defines predictive coding to compensate for interference, is outlined in [20]. In [22], the authors have proposed a novel wireless scheduling building design to explore the coordination gains of sensing, communication, and computation from the perspective of joint optimization.

The resource allocation using the filtration approach is outlined in [21], where a Kalman filtration approach is used in the development of resource allocation in a scheduler unit. Although the presented method proposed resource allocation using Kalman Filter, the scheduling is developed based on the past flow of information. In [22], the author highlights the technological effects of Wireless Communication in different applications.

The dynamic channel variation, which is non-linear, results in false updation in such estimations. The convergence delay is considerably large in this case. To overcome the issue, this paper proposes a new approach to the scheduler unit based on an allocation and interference model for updated Kalman filtration.

The rest of the paper is outlined in 6 sections, where section 2 outlines the existing approach of scheduler design using the Kalman Filter. The proposed approach of the scheduler with interference monitoring is presented in section 3. Section 4 outlines the simulation result for the proposed approach. The conclusion is presented in section 5.

2. Kalman Filter-Based Scheduler

In allocating a Resource Block (RB) in Wireless Communication, various approaches of allocation strategies have been proposed in the past. In recent, a Kalman filter-based approach was presented in [1] for an optimal allocation of resource blocks. In the Communication System for a given flow of data with a data rate of k, a resource block RB is allotted using a scheduler design. This scheduler has been proposed for resource block allocation based on the best traffic model.

The resource is allocated based on the measured throughput for least traffic condition in the allocation process. The proposed scheduler uses the information of past resource allocation in throughput monitoring, which is given by

$$\overline{T^{u}_{i,j}} = r^{i}_{j}(t) / D^{l}(t-1) \qquad (1)$$

Here, $\overline{D}^{l}(t-1)$ defines the estimate of i^{th} flow for the past Transmission Time Interval (TTI) with a data rate of $r^{i}_{j}(t)$ allocated for a Resource Block RB.

For each transmission interval, the rate of transmission is defined by

$$\bar{D}^{j}(t) = \beta\bar{D}^{j}(t-1) + (1-\beta)\, D_t \quad (2)$$

The estimation of the rate allocation is performed using the Kalman Filter. Here, t is the time stamp for the rate allocation. The Kalman Filter parameter is estimated based on the process of prediction and estimation. Here a priori estimate is of the state S, which is developed based on the projected covariance error. The estimate of the Kalman Filter is given by

$$\hat{I}_t = A\,\widehat{I_{t-1}} \quad (3)$$

$$P_t = AP_{t-1}A^T + Q \quad (4)$$

The Kalman gain is used in deriving the prediction coefficient and estimation coefficient $\hat{P}_t$ and $\hat{I}_t$, respectively. For every prediction loop, the estimate is derived based on the gain and the offered data rate for communication. The Kalman gain is estimated with an increment of each loop, and variable k is increased by 1 for each loop. The estimation process reset the values of $\hat{I}_t$ and $\hat{P}_t$. Here, A defines the state of the system at timestamp t-1 to t, and M relates the system measurement by the relative function

$$f = M\,I_t + \vartheta \quad (5)$$

The measured factors Q and ϑ define the computed noise and covariance of the system. The updation of the estimated coefficient here is defined by the allocated rate in the present state and the rate allocated in the previous state. The estimate is derived based on the noise variance and covariance factor. The estimate is derived as,

$$\hat{I}_t = \widehat{D_{t-1}} \quad (6)$$

$$\hat{P}_t = P_{t-1} + Q \quad (7)$$

$$D_t = \hat{I}_t + K(\hat{I}_t - r^i_j) \quad (8)$$

The allocation of the data rate is defined as a function of the past allocated data rate with Kalman gain K. The estimate is subjected to the minimization of error covariance $\hat{P}_t$. The estimate of rate allocation has a significant improvement in the system throughput and its accuracy. However, the impact of resource allocation with variation in user density and channel interference has a dynamic effect on the estimated performance. The allocation of data rate is hence optimized by a new scheduler design based on the interference and user dynamicity in the network.

3. Improved Estimation and Scheduling Approach

In the wireless communication process, the dynamic channel variation leads to random interference, and data rate allocation directly impacts the quality of the service offered. In controlling data rate allocation, various scheduler approaches were integrated to obtain efficient transmission control in the channel. The schedules were developed with different approaches wherein in [1], a rate control based on an estimation approach following the Kalman filter is proposed. The approach follows the estimation method based on covariance error in the allocation of data rate. The allocation approach, however, does not consider the allocation process of RB under varying node parameters. The communication unit is developed with a resource allocation block in developing an optimal scheduler design. The proposed approach is interfaced with a scheduler unit in monitoring and allocation of communicating data rate, as shown in Figure 1. The proposed scheduling approach is presented, where the given resource demand is passed to the Scheduler unit, wherein this unit performs a resource allocation based on the available bandwidth and the distortion level observed at the channel. The scheduler is defined with the processing approach of distortional coding. This coding is defined to have rate and distortion monitoring for best resource allocation giving a higher accuracy level in Data streaming.

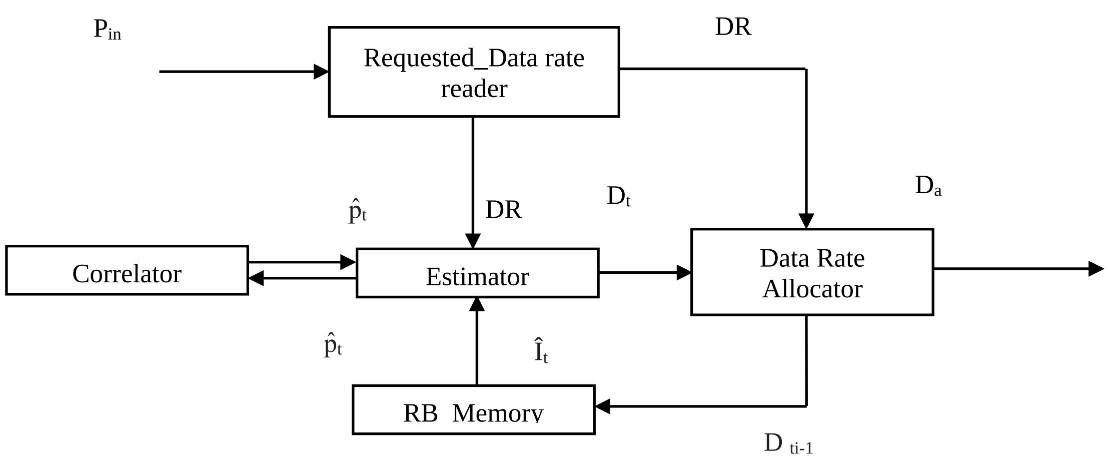

Fig. 1 Block diagram of proposed Scheduler Unit

Table 1. RB_Memory unit

Active users	Allocated RB with Data rate
U_1	$RB_{1,10}$
U_2	$RB_{1,3}$
U_3	$RB_{1,6}$
:	:
:	:
:	:
:	:
U_n	$RB_{n,10}$

The proposed approach monitors the demanded data rate, observes the service required and processes the data rate allocation based on the available data rate. This is done after the correlation of correlative error and interference level. In addition to the estimation and allocation process of the existing system, our approach also proposes a monitoring scheme based on the aggregated data rate of communication of the complete network data rate. The Correlator unit performs a feedback error computation based on the input sequence and the past knowledge of allocation ($\hat{I}_t^-$). The estimate is developed based on the network's user density, which is proportionate to the RB allocation and interference in the channel. The scheduler records the RB allocation and computes the allocation data rate based on the minimization of covariance error. The formation of an RB allocation table is shown in table 1.

The computing unit observes the number of active users in the network and performs an RB allocation schedule. The process of scheduling is illustrated below.

3.1 RB scheduling and allocation Algorithm

For estimate = '1' (the process of covariance computation)

For t='1'; Gen_req_pkt

For t = 2; Enable_Correlator

For t=3, Read feedback signal (fs)

Compute _error (e) = cov (fs, fs-)

If e<=e-

Allocated _D = Demanded _D

Else

Fractionize Demanded _D to converge min(e)

End

Table 2. Network Simulation parameter

Network Parameters	Values
User Bandwidth	5 MHz
No. of RB	25
Users in network	10 – 40
Network Pattern	Random
Cell Radius	0.5 Km

The f ractionalization is developed for the data rate available with the estimated data rate given as

$$Da = \begin{cases} DR, & \text{if } \hat{P}t < \hat{P}t^- \\ DR - \frac{Dt}{k} & \text{if } \hat{P}_t \geq \hat{P}t^- \end{cases} \quad (9)$$

Where, DR is the Data Rate for allocation. The value of data rate allocation (D_t) is estimated using the Kalman filtration approach, where the estimate is defined as the function of covariance error subjected to the number of active users in the network. As outlined, the control operation of data rate allocation is governed by the covariance error $\hat{P}_t$. The allocated data rate D_a is increased by the estimate D_t if the covariance error is lower than the previous covariance error. The data rate is changed to (DR $-D_t$) if the current covariance error $\hat{P}_t$ is k observed to be higher than the previous covariance error ($\hat{P}_t^-$) Where, k is a constant decimation factor. The estimate function of the Kalman filter is updated as

$$\hat{I}_t = \sum_{i=1}^{N} \widehat{D_t}\, t\text{-}1 \quad (10)$$

$$\hat{P}_t = (P_{ti} - P_{ti-1}) + Q, \quad for\ i = 1 \ldots N \quad (11)$$

$$D_t = \hat{I}_t + K(\hat{I}_t - DR^i_j) \quad (12)$$

The state variable of an apriori estimated ($\hat{I}_t$) is defined as the aggregated data rate allocation of past observation ($\widehat{D}_{tl-1}$) observed for N active users. The covariance error is defined as the successive correlation of user i and (i-1). The estimated allocable data rate (D_t) is defined as the function of Kalman Gain K with available data rate for users i to j. The allocation is controlled over the past allocated data rate and the available data rate.

4. Results and Discussion

The evaluation of the proposed system is performed for a randomly distributed network with varying node densities. The parameter of the Simulation used is listed in table 2.

The randomly distributed network is illustrated in figure 2. The placement of the user in the network is taken at random. The nodes are defined with a distinct identification number, allocated bandwidth, and node power.

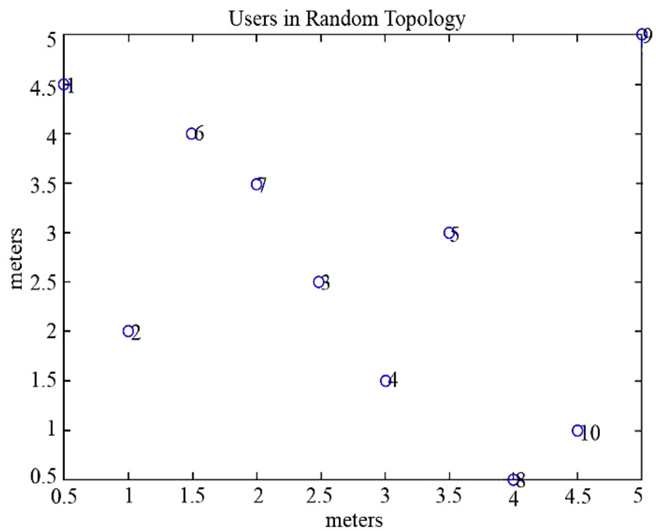

Fig. 2 Randomly distributed network with 10 users in the network

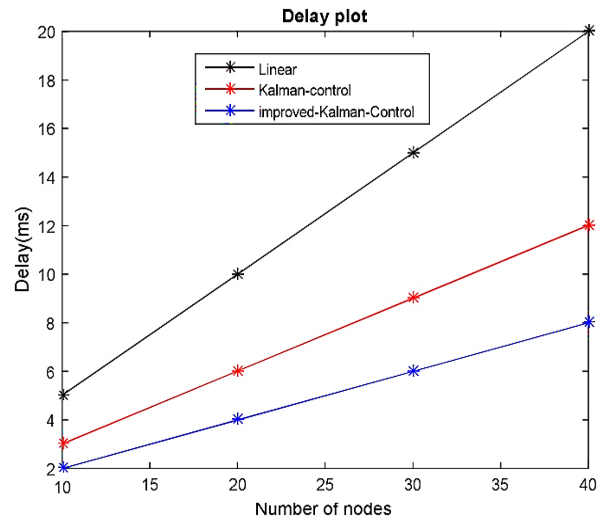

Fig. 4 Observed delay for the developed model

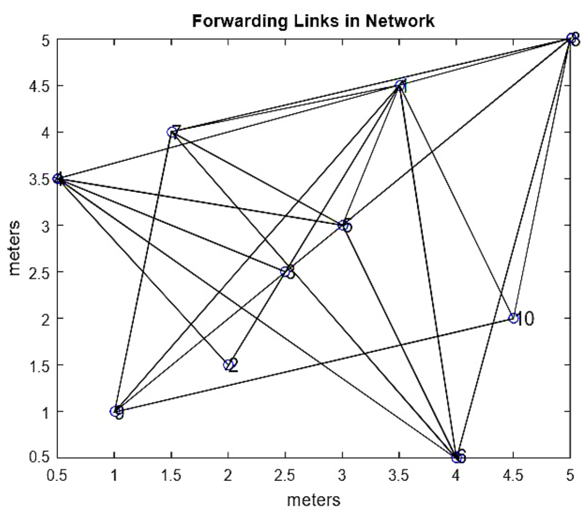

Fig. 3 Links for data exchange in the network

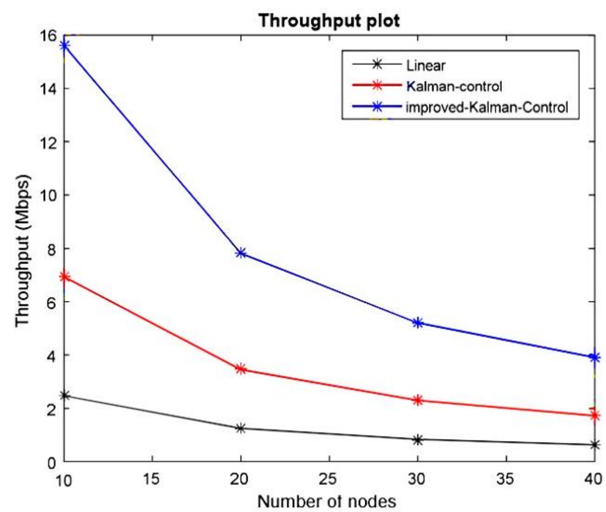

Fig. 5 System throughput for the developed network

Each user is processed to discover the uplink node based on communication range constraints. The users are processed to broadcast the link request packet for establishing link terminals. The possible links for the simulated node are presented in figure 3. Each of the links is registered to all interconnected nodes, which are further used in data exchange.

The network simulation is developed with a random selection of source and destination; in this case, it is taken as 3 and 12, respectively. The communication is performed over 4 sub-channels processed over variant additive white Gaussian noise (AWGN). The signals are propagated using a wireless medium where the channel SNR is varied to observe the efficiency of the estimation process. The observations for the developed approach are illustrated in the figure below.

The delay is observed with the variation in the number of nodes in the network. Delay is the total time taken to process and communicate forwarding packets. It is observed that the proposed Kalman-based Resource Scheduler has minimal delay compared to the existing linear and Kalman-based approaches. The improved scheduler monitoring of users in the network offers a controlled data rate for communication.

The Improved Kalman approach illustrates a higher system throughput due to faster and more accurate availability of resources. The estimation of allocating data rate is developed based on the covariance error, which obtains a higher throughput in the network. The network Throughput
(T) of the system is given as,

$$\text{Throughput (T)} = \frac{TD_e \times tm}{TDg} \qquad (13)$$

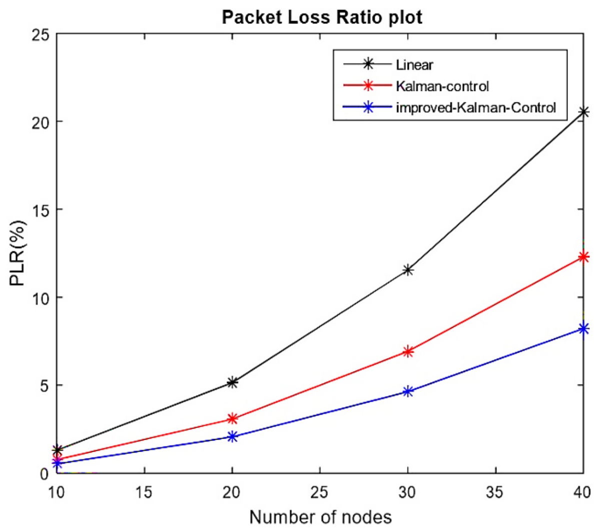

Fig. 6 Observed packet loss ratio for the developed approaches

Where,
TD_e – Total exchanged data packet
TD_g – Total generated Data packet
t_m - observation Time

To evaluate the accuracy of the simulated system, the packet loss ratio (PLR) is observed. Figure 6 illustrates the observed Packet Loss Ratio for the developed approach.

The packet loss ratio is developed based on the quantum of packets forwarded over the number of packets correctly received for a given time period. This illustrates the loss of information in the network. The proposed approach illustrates a lower packet loss compared to existing approaches. The loss in information is due to the blockage in the random allocation of data rate, which introduces delay when congested and hence results in packet loss condition. In the proposed approach, the data rate is controlled by monitoring the number of active users participating in the communication, which results in a lower blockage level and minimal loss of packets. A similar observation is developed for a network with an SNR of 10dB and 30 users. The observations are illustrated in the figure 7.

Like in figure 2, a randomly deployed user network is shown in figure 7 for a greater number of users. Each user or node is assigned an ID, allocated bandwidth, and node power.

Figure 8 shows all the possible links for a particular node in the network. Nodes which are within the range are computed, and the nearest possible node is selected for communication.

Simulation is carried out by assuming the 3rd node is the source node and the 10th node is the destination node.

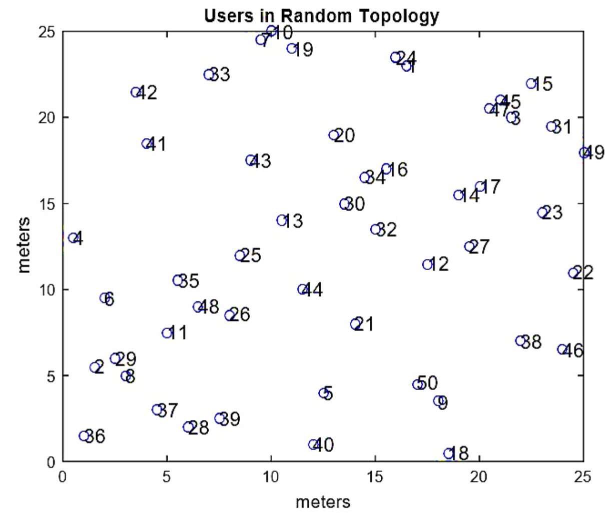

Fig. 7 Randomly distributed network with 60 users in the network

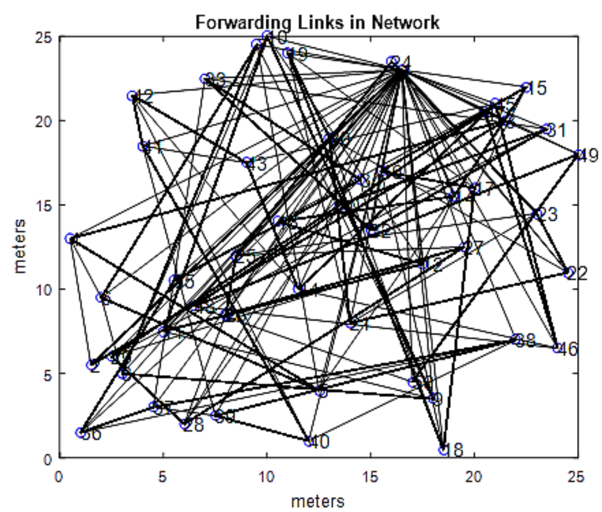

Fig. 8 Links for data exchange in the network

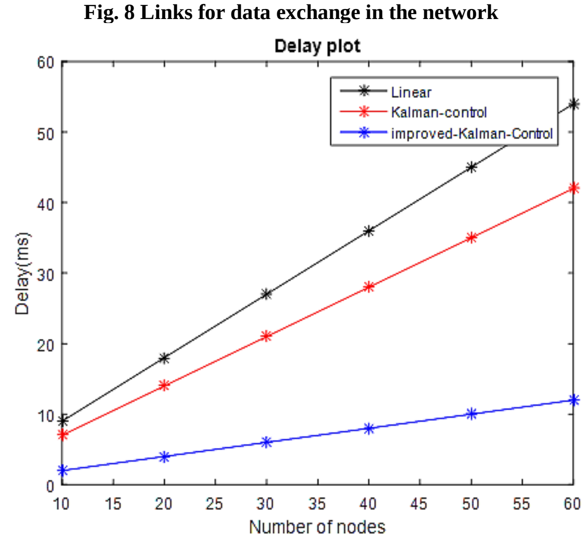

Fig. 9 Observed delay for the developed model with 60 users in the network

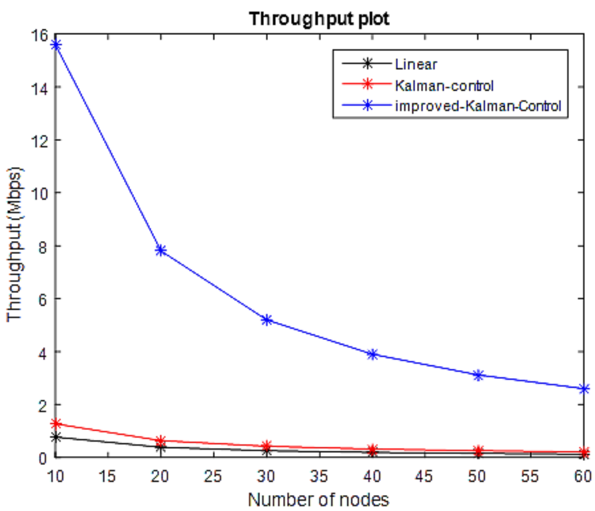

Fig. 10 System throughput for the developed network

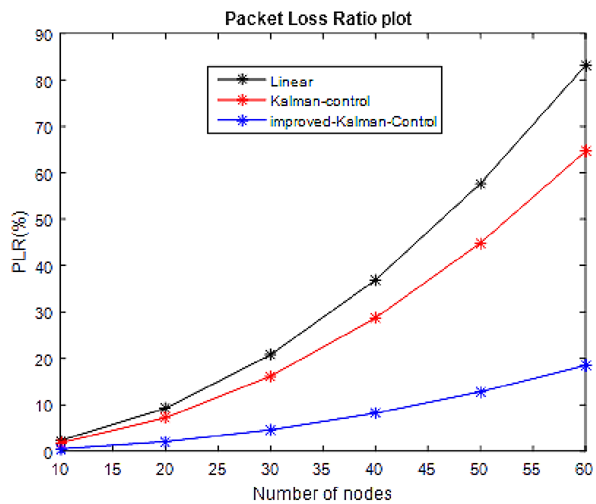

Fig. 11 Observed packet loss ratio with 60 users randomly deployed in the network

It is observed in Figure 9 that the performance of the proposed approach is far better than the existing methods with respect to delay in communication. This is due to the use of controlled allocation of data rate for multiple users in the Improved Kalman approach, which reduces the traffic or blockage in the communication channel.

Figure 10 shows a considerable increase in the system throughput in the proposed method for multiple users compared to the existing methods. This is a result of controlling data rate allocation based on the present throughput and the traffic condition of the channel.

The performance of the suggested approach for Packet Loss Ratio in the case of the increased number of users in the network of communication is depicted in figure 11. PLR is minimized due to controlled resource scheduling.

5. Conclusion

An approach of Resource Scheduler based on an improved Kalman Filter is proposed. This approach develops the data rate allocation based on governing node density and the covariance error.

The Kalman filter state updation is improved with the node density parameter by introducing rate control to active users monitoring and error minimization. The proposed approach controls the data rate allocation governing posteriori covariance estimate and computes the allocable data rate based on minimal covariance error.

Compared to the existing Linear method and Kalman Control, the proposed approach observed minimization in the delay of data exchange, resulting in increased network throughput (more than 10 times) and lower packet loss ratio.

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