Volume 2, No. 1, January 2011
Journal of Global Research in Computer Science
ISSN-2229-371X
RESEARCH PAPER
Available Online at www.jgrcs.info

WIENER PREDICTION BASED HANDOFF CALL RESOURCE MANAGEMENT IN WIRELESS MOBILE MULTIMEDIA NETWORKS

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Abstract: The objective of wireless mobile multimedia networks is to allocate required amount of resources to a mobile multimedia call. Reserving the resources in advance to a future new and handoff call is better than rejecting a call at neck of the moment due to insufficient resource at a particular time. This work presents an efficient handoff resource management method by considering the future resource demands of a wireless multimedia call. Here wiener prediction based resource estimation and reservation method is adopted to estimate the instantaneous resource demands of a mobile call. Cell segmentation technique is introduced and utilized to predict the resource demands more accurately in a real time manner. The simulation result shows the synergy of resource reservation using wiener prediction and cell segmentation have been decrease the call dropping probability of the handoff calls and enhance the micro and pico cellular system performance in real time manner..

Keywords: Handoff(HO), Resource Estimation(RE), Resource Reservation(RR),Cell Segmentation(CS),Wiener Prediction(WP), Call Dropping Probability (CDP), Wireless Multimedia Networks (WMN).

INTRODUCTION

Resource allocation is done to ensure an efficient use of resources in the wireless network. Radio resource allocation in cellular mobile system focuses mainly to improve the user admission capability and protecting the connection continuity. Handoff (HO) is an operation in which Mobile Unit (MU) communicating with one wireless Base Transceiver Station (BTS) is transferred to another base transceiver station during a call. A wireless mobile call in progress could be forced to abort during handoff, if it cannot be allocated sufficient amount of resources in the new wireless cell. A cell is the radio coverage area of a wireless base transceiver station. Present wireless cellular systems are employed with mobile assisted soft handoff technique for handoff operation. Handoffs are critical in cellular mobile system because neighboring cells are always using a disjoint subset of frequency bands. Hence negotiations must take place between mobile units, the current serving base transceiver station and the next potential base transceiver station.

Reserving resources for future handoff calls and new calls is an effective way to reduce the handoff call dropping and new call blocking probability. Predicting and reserving resources for future calls can be classified into two types. They are local and collaborative methods[1]-[5]. Existing collaborative and local methods for resource reservation requires each base transceiver station to gather real time information on the behaviors of mobile units in neighboring cells. Such information may include how many users are expected to be handoff and service class of multimedia call in the neighboring cells at a given time. Local methods [6]-[8] assumes that every call requires the same bandwidth, the call arrival process is poisson, and the call holding time and a particular call channel holding time in each cell is exponentially distributed. Service class of a multimedia call mainly deals with how much amount of resource required for each call request. In the real time environments gathering the above information in a very short duration is very difficult one.

The mobility-dependent predictive resource reservation (MDPRR) scheme and an admission control scheme are proposed in [9] based on common handoff procedure to provide flexible usage of scarce resource in mobile multimedia wireless networks. NPS(neural-network prediction scheme) is proposed in [10] to provide high accurate location prediction of a MH (mobile host) in wireless networks. In order to avoid too early or over reservation resulting in a waste of resources, a three-times resource-reservation scheme (TTRR) is also proposed .The work in [11] is based on application of multi-input-multi-output (MIMO) multiplicative autoregressive-integrated-moving average (ARIMA) (p,d,q)x(P,D,Q)s models fitted to the traffic data measured in the considered cell itself and on the new call admission control (CAC) algorithm that simultaneously maximizes the system throughput while keeping the handoff call dropping probability (CDP) below the targeted value. The mobility-aided adaptive resource reservation (MARR) with admission control (AC) based on cell division , to provide better usage of scarce resource in wireless multimedia networks is proposed in [12]. The effect of pre-reservation area size on handoff performance in wireless cellular networks are discussed in [13]. It shows that if the reserved channels are strictly mapped to the MSs that made the corresponding reservations, as we increase the pre-reservation area size, the system performance (in terms of the probability that the handoff calls are dropped) improves initially. The optimal pre-reservation area size is closely related to the traffic load of the network and the MSs' mobility pattern (moving speed).

LIMITATIONS OF AVAILABLE METHODS

Existing local and collaborative methods for predicting and reserving resources for future handoff calls and new calls are not much suitable for wireless multimedia networks. This is because of the following reasons.

The amount of resource required to successfully handoff a call may vary over a wide range in a multimedia wireless networks. For example, data and video application calls may require different service quality levels and consequently require different amount of resources in order to ensure a successful handoff. Wireless networks are often consist of large number of micro and pico cells (i.e., very small radius cells). In such networks, handoff becomes more frequent, handoff call arrivals may be non-poisson and non-stationary for extended periods of time, and a handoff call channel holing time distribution inside each cell can be arbitrary. Even in macro cellular networks, handoff call arrivals may often be non-poisson and non-stationary for extended periods of time. For example, handoff call arrival rates will vary with the number of mobile users, user mobility pattern and network configuration.

Speed of mobile units may vary widely and mobile users may stay in a particular micro or pico cell for very short time periods. Hence gathering real-time information on current status and behaviors of mobile units in other cells and communicating such information among base transceiver stations in a timely fashion will increases the system complexity and cost.

The limitations of existing methods caused primarily by, they do not model the resource demands of handoff calls and new calls directly. In a real multimedia wireless networks, number of factors can impact the resource demands of future handoff calls and new calls. They include cell sizes, network configuration, number of mobile units in each cell, speed and mobility pattern of mobile units, types of services supported in each cell, types of services used by each mobile unit at any given time, arrival processes of new and handoff calls, call and channel holding times, etc. These factors often have a complex correlation and the set of the factors often changes over time. Consequently, modeling these factors can be difficult, especially when only local information is available. This is primarily why most existing collaborative and local methods can only handle poisson and stationary call arrivals, and requires each radio channel to have the same capacity.

In this work a new class of Cell Segmentation (CS) based new call and handoff call resource estimation and reservation method is proposed. This overcomes some of the critical limitations of existing methods by modeling the instantaneous amount of resource demands directly. The proposed RER method uses pilot sensing method to gather information. This method perform well for new and handoff call arrival processes are non-poisson and non-stationary and each call requests an arbitrary amount of resources i.e. limit allowed by the network and has non-exponentially distributed call and channel holding times.

KEY FEATURES OF PROPOSED RESOURCE ESTIMATION AND RESERVATION (RER) METHOD

Here a new class of dynamic resource estimation and reservation method for supporting multimedia call is proposed. The proposed RER method has the following properties.

- *Localized prediction*: Each base transceiver station uses local available information from neighboring cells to determine dynamically how much resource should be reserved for future handoff calls and new calls. It communicate with other base transceiver stations for resource reservation decision, depends upon Predetermined Time Interval (PTI).
- *Modeling instantaneous demands directly*: The proposed method models the instantaneous values of resource demands directly by using cell segmentation. It also enables to predict instantaneous and average future demands, while other existing methods can typically predict only average demands.
- *Multimedia call resource estimation and reservation*: The proposed method estimates the future resource demands of each individual service class of multimedia call directly. It can also estimate the total amount of resource required for handoff calls and new calls of all service classes of a multimedia call.
- *Simplicity*: The proposed method is much simpler to implement in real time and existing networks.

PROPOSED RESOURCE ESTIMATION AND RESERVATION METHOD

The proposed resource reservation method for handoff calls is shown in Figure 1 and is a self explanatory one. When a mobile unit is approaching towards the cell boundary, its position and velocity are monitored. By using this, its remaining time in the current cell is calculated. Once this time falls below the threshold value called Resource Reservation Interval (RRI), then an new channel reservation request is sent to the test or target cell.

If there are free or ideal channels in the target cell, then one channel is immediately reserved. At the same time, the channel is locked and temporarily disabled for other usage in the target cell. If the target cell has no free channels, then the reservation request waits for predetermined time interval. When a channel is released in the target cell within PTI, then that free channel is assigned for demand request. If there is no reservation request arrives then the released channel is remains free until the next channel request arrives. When a mobile unit ends its call connection in the current cell, but moving towards the target cell, in this case, a reservation cancellation request is forwarded to the target cell. Upon receiving the cancellation request, the target cell releases the locked channel or clears the reservation request.

When the mobile unit enters the target cell, handoff will be successful only if a channel has been reserved to take it over, or blocked if its reservation request is not yet processed. In the former case, the mobile unit continues its call, on the new channel until leaving or call completion, while in the later case, the call is forced into termination. A new call is accepted only if a free channel exists upon its arrival. Otherwise it is blocked and cleared from the system i.e. in the channel servers. For new calls, there is no need of resource reservation. Once free channels are available, and then connection is established. Otherwise the caller has to wait until the availability of free channels in the current cell. But for handoff calls, the resource reservation in advance is a mandatory one.

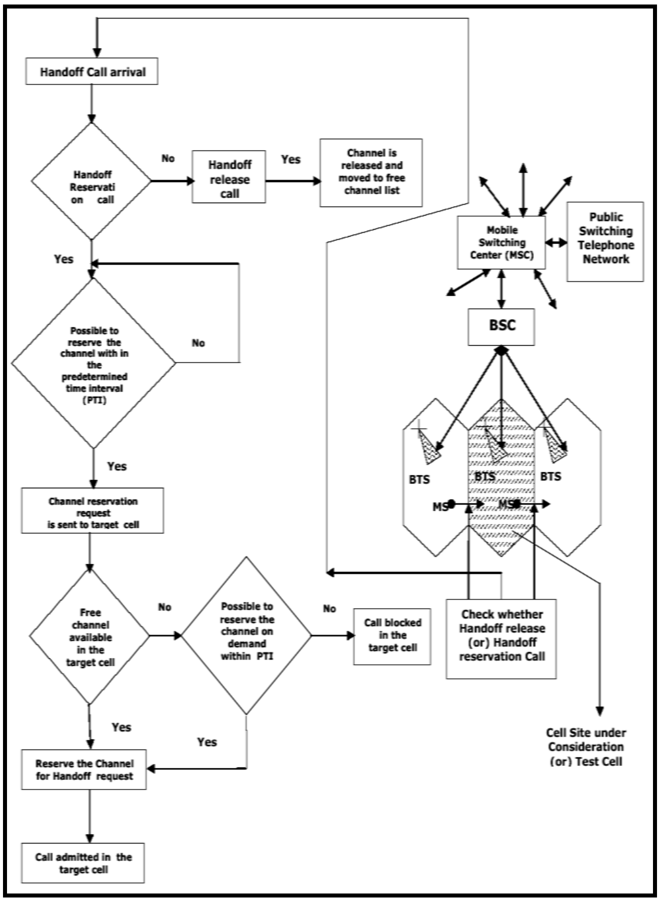


Figure 1. Proposed Handoff Call Resource Reservation Method

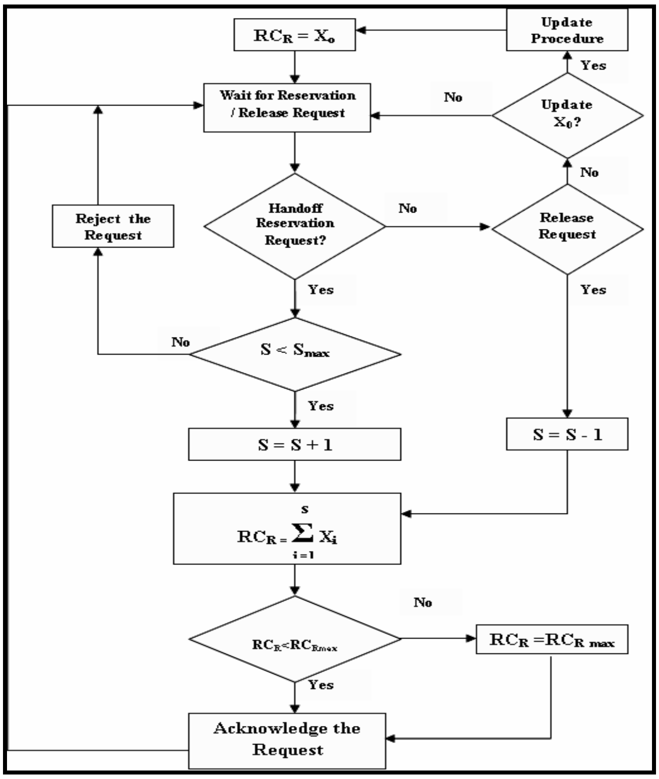


Figure 2. Flow Chart for Resource Reservation / Release Operations

RC_R	-	Reserved Resource Capacity
RC_{Rmax}	-	Maximum Reserved Resource Capacity
S	-	Number of reservations

FLOWCHART FOR RESOURCE RESERVATION/ RELEASE OPERATIONS

The flow chart for channel reservation /release operation is shown in Figure 2.

- The reserved resource capacity $RC_R(S)$ is initially set at X_0 and Base Station Controller (BSC) waits for reservation request.
- When a channel reservation is requested by mobile unit, the associated BSC accept the request, if the number of reservations 'S' in BSC is smaller than the predetermined maximum value of S, S_{max}.
- In the case of acceptance of the reservation request, the BSC increases 'S' by one and increases RC_R (S) by X_S. Which can be properly set at a different value for each 'S', if the reserved capacity $RC_R(S)$ is less than the RC_{Rmax}. Otherwise the RC_R (S) is set at RC_R max.
- When the release of the reserved channel capacity is requested, the BSC decreases 'S' by one and RC_R (S) by X_{S+1}, if $RC_R(S)$ is less than the RC_{Rmax}, otherwise $RC_R(S)$ is remains at RC_{Rmax}.

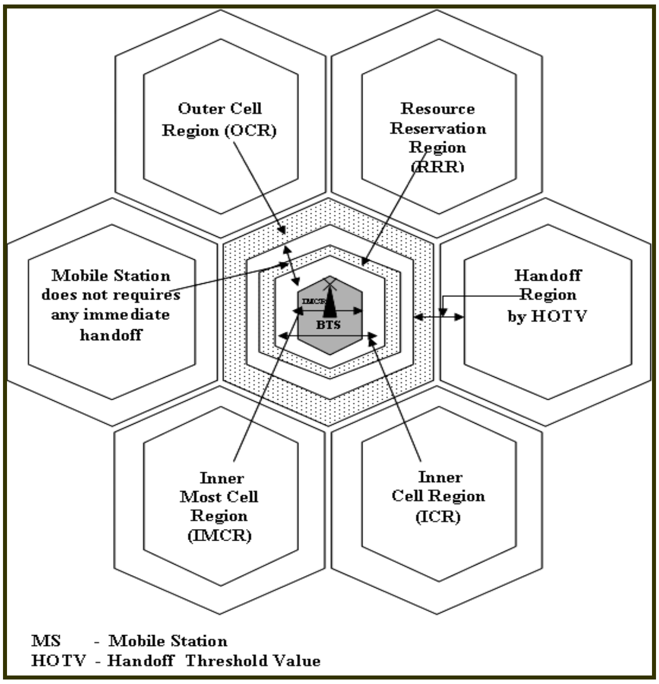
This method of pilot sensing reservation mechanism reduces the unnecessary blocking of new calls and dropping of the hand of calls. Since the system capacity depends on the new call blocking and handoff call droppings. The system capacity is limited by new call blocking if the new call blocking probability is higher than the weighted sum of the handoff call failure probability. If the weighted sum of the handoff call failure probability is higher than the new call blocking probability, the excursive handoff call failure probability limits the system capacity.

The system capacity is maximum, when the new call blocking probability is equal to the weighted sum of the handoff dropping probability. To keep a balance between the new call blocking and the handoff call dropping probability, this method controls the size of the minimum reservation capacity X_o by counting the number of new call blocking and handoff call droppings. For resource reservation, new calls and handoff calls are taken into account, and the Markov model shown in Figure 4 can be used to reduce the computational complexity.

CELL SEGMENTATION FOR RESOURCE RESERVATION / RELEASE OPERATIONS

For effective resource reservation process as well as the handoff process, the cell area is divided in to the following regions. It is shown in Figure 3. They are

- The Inner Cell Region (ICR)
- Inner Most Cell Region (IMCR)
- The Resource Reservation Region (RRR)
- Handoff region by Handoff Threshold Value (HOTV).
  BHOTV – Below Handoff Threshold Value
- The Outer Cell Region (OCR)



	MU Resource Release conditions	MU Resource Reservation Conditions
1.	IMCR to RRR - does not require any immediate handoff	RRR to IMCR - Does not require any reservation
2.	RRR to outer cell region requires the channel release in the current cell	MU entering from neighboring cell to test cell outer region then test cell requires immediate handoff reservation

Figure 3. Cell Segmentation for Resource Reservation/Release Conditions

A Communicating MU requires Resource Reservation for the following conditions

- When the mobile unit moves from RRR to IMCR then it does not require any immediate resource reservation.
- When the mobile unit enters from the neighboring cell outer boundary i.e OCR to the test cell outer region, then immediate reservation is required in the test cell.

A communicating mobile unit does not require any further resource reservation for the following conditions.

- The call of a communicating mobile unit is terminated with in the RRR.
- The mobile call is terminated with in the IMCR after the caller moves from RRR to OCR.

A Communicating mobile unit in RRR region requires another reservation for the following conditions.

- A communicating mobile unit moves from RRR to IMCR and moves back into the RRR region again.
- A communicating mobile unit moves from the RRR to another RRR.

When the mobile unit moves from RRR to HOTV i.e. handoff threshold value, then the threshold value of the received signal in the MU decreases and handoff occurs. This handoff is a handoff release process and the channel is kept in the Base Station Controller (BSC) or Mobile Switching Centre(MSC) pool for allocating this channel into other channel reservation requests. When a new call arrives in an RRR region, then it requires an immediate channel reservation if it is not blocked.

MARKOV MODEL

In the Markov process discussed by Lee[14] and Taha et al[15], future value is independent of the past values, given in the present value. i.e. It can models the future, depends only upon the present state. The Wiener process and Poisson process are Markov process. Since, both have the properties of independent increment, in a continuous time space. If the call arrival at a particular time interval is minimum in numbers, then poisson process is suggested. If the call arrival at a particular interval of time is maximum in numbers, then Wiener process is suggested.

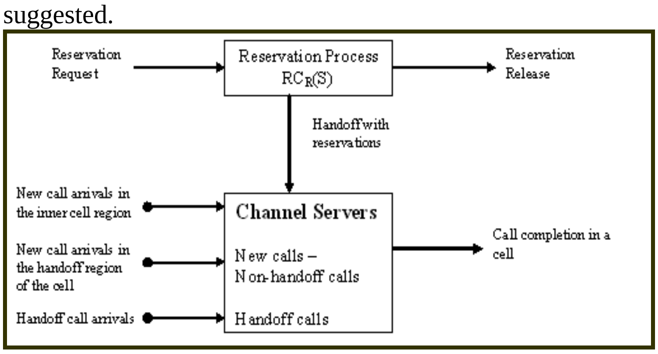


Figure 4. Markov model for new call, handoff call and resource reservation call arrivals

Here Wiener process is suggested, since in micro and pico cellular systems, call arrivals in a particular time interval is maximum in numbers. New call arrivals, handoff call arrivals and reservation request arrivals based on the Markov model is shown in Figure 4. for resource reservation conditions. New call arrivals in a handoff region are admitted only if both of the associated base transceiver stations accept, and, if they are admitted, the calls go into handoff. A handoff arrival with a channel reservation enters the system as a reservation request arrival. When the reservation is released, it is assumed that, the release is caused by a handoff attempt. Service for a reservation request arrival is completed either if the call of the MU that requested the reservation is terminated or if the MU moves out of an RRR region.

A. Wiener Based Prediction Method

The proposed technique for resource reservation is wiener based method discussed by Taha et al[15]. This method supports multimedia calls since multimedia calls are variable bandwidth calls and it supports poisson and random arrival of calls in the network. It also supports stationary and non-stationary call arrivals in the system. In the wiener process, the present and future values are affected by large number of independent or weakly dependent factors. Since in the wireless cellular network, all calls are continuous with respect to time but discrete with respect to events in nature. The expression for estimating future demand by using present demand and present estimated demand is given by

$$\hat{D}_{t+1} = (1-\alpha)\hat{D}_t + m\alpha D_t \quad (1)$$

where,

D_t - Observed demand of the mobile unit a time 't'

$\hat{D}_t$ - Estimated demand of the mobile unit at time 't'

$\hat{D}_{t+1}$ - Estimated demand of the mobile unit at time 't+1'

α - Smoothing factor lies between zero and one

m - Amplification factor according to the value of alpha (α)

Δt = 't+1' - Estimation time interval – 10 minutes

When $\alpha = 0$

$\hat{D}_{t+1} = \hat{D}t \Rightarrow$ Future estimated demand is equal to present estimated demand and,

When $\alpha = 1$

$\hat{D}_{t+1} = Dt \Rightarrow$ Future estimated demand is equal to present demand, so from α = 0.1 to 0.9 future estimated demand is calculated.

To calculate the demand more accurately, the value of 'α' is calculated as

$$\alpha = C\frac{Es^2}{\sigma_{t+1}}, \quad (2)$$

where 0<C<1

In equation (2),

$Es = Dt - \hat{D}_t$ is the prediction error, and

$\sigma_{t+1} = CEs^2 + (1-\alpha)\sigma_t$, Since '$\alpha$' is standard normal variable and the value should lies only between zero and one

$\sigma_t \Rightarrow$ std deviation at time 't'

$\sigma_{t+1} \Rightarrow$ std deviation at time 't+1'

The wiener estimation method has the following properties

- $\Delta R = \hat{D}_{t+1}$ is modeled as normal random variable for a given Δt = t +1. Normal distribution is justified because 'α' is the standard normal variable and the present and future values affected by large number of independent or weakly dependent factors.
- The values of $\Delta R = \hat{D}_{t+1}$ for any two disjoint time intervals are independent in nature.
- The value $\Delta R = \hat{D}_{t+1}$ for the given time interval Δt =t+1 is independent of starting time interval.
- $\Delta R = \hat{D}_{t+1}$ has mean zero and standard deviation $\sqrt{\Delta t}$.

PERFORMANCE EVALUATION AND CONCLUSION

The analysis of wiener based future resource estimation using present demand and present estimated demand is given in section 7.1. By varying the smoothing factor alpha, it can predict the future estimated demand more accurately. The performance of a proposed wiener based resource estimation method is shown in Figures 5 and 6. Figure 5 shows linear and Figure 6 shows the non-linear estimation of resource demands of a mobile unit in a predetermined time interval. The proposed method utilizes the cell segmentation effect for resource estimation and reservation.

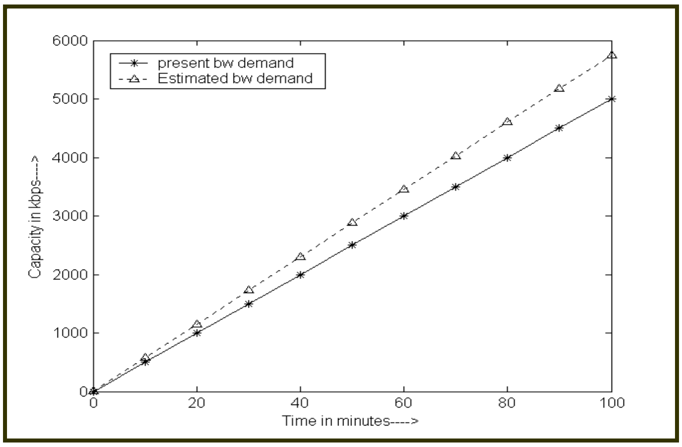


Figure 5. Resource Estimation Using Proposed Wiener Method – Linear Prediction

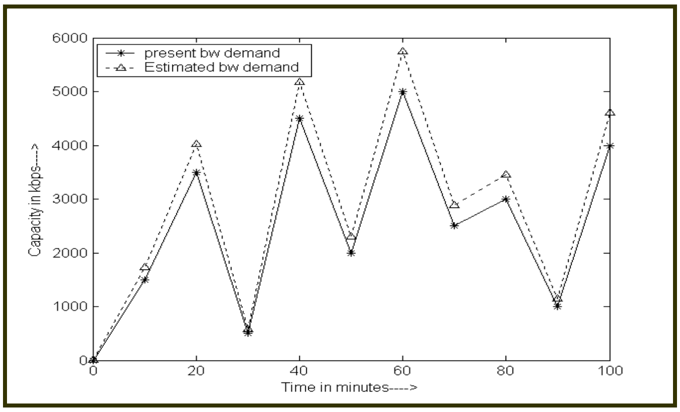


Figure 6. Resource Estimation Using Proposed Wiener Method– Nonlinear Prediction

Assuming each cell can support up to 78 channels and the target Call Dropping Probability (CDP) is 5%. The call arrival rate is varied to allow a comparison of CDP between lightly loaded and heavily overloaded systems. From the simulation it is shown that, using the predictions generated by the proposed RER, based on wiener method and the existing method, the resulting CDP is comparably reduced. Utilizing the cell segmentation effect for resource estimation and resource reservation for future handoff calls effectively utilizes the available resources.

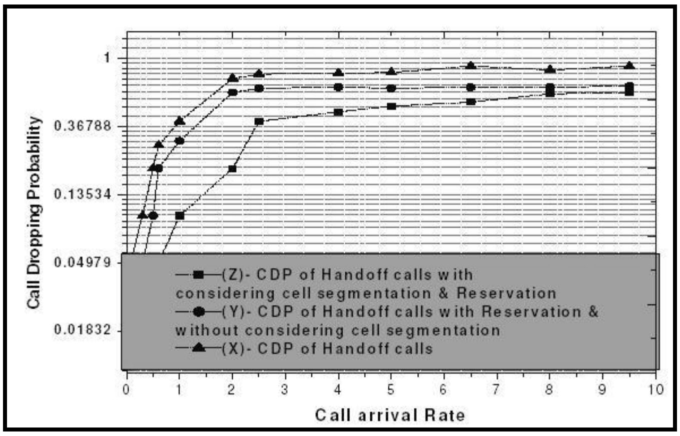


Figure 7. Handoff Call Dropping Probability Comparison between Existing and Proposed Method

Figure 7 shows the call dropping probability of handoff calls with and without considering the cell segmentation and resource reservation effects. In this graph, curve ‘x’ shows the CDP of handoff calls for existing methods of local and collaborative methods. Curve ‘Y’ shows the CDP of handoff calls with resource reservation and without considering the cell segmentation effect. In this case the CDP of lightly and heavily loaded system is constantly reduced by an amount of 15 percent when compared with existing methods. Curve ‘Z’ is the response result by utilizing the cell segmentation effect for resource reservation. Now the performance is initially improved by an amount of 35 percent in the lightly loaded system and when the call arrival rate is increased, it produces an improvement of 20 percent reduction in CDP for heavily loaded system as compared with existing methods. With considering cell segmentation for reserving the resources considerably reduces the call dropping probability of handoff calls than without cell segmentation. This synergy of resource reservation and cell segmentation effectively manage the available resources in the network and will increase the micro and pico cellular system performance in real time manner. In this work more concentration given to handoff calls because termination of an ongoing call during handoff due to insufficient resource will onset the mobile users more than the new call termination during the call initiation.

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