Cost Analysis of Location Manager based Handover Method for LEO Satellite Networks

Debabrata sarddar(Asst. Proff.)
Department of C.S.E.
University of Kalyani

Dipsikha Ganguly
Department of E.T.C.E.
B.P.Poddar I.M.T.,WBUT

Soumya Das
Department of E.T.C.E
Bengal Institute of tec.WBUT

Suman Kumar Sikdar
M. Tech in C.S.E

Sougata Chakraborty
M.Tech in C.S.E.
Jadavpur University

Kunal Hui
M. Tech in C.S.E

Shabnam Bandyopadhyay
Department of C.S.E
Jadavpur University

Kalyan Kumar Das
Department of C.S.E
Jadavpur University

Sujoy Palit
Department of C.S.E
W.B.U.T

ABSTRACT
Low Earth Orbit (LEO) satellite made a great effect to the scientists towards the end of the previous decade because of its some interesting features such as low propagation delay, low power requirements and the ability to communicate with handheld terminals. That's why future satellite networks are now conceived as complementary rather than competitive to terrestrial networks. But as the speed of LEO satellite is higher than Mobile Nodes (MN) and earth's speed, the no of handover occurrence is more which degrades the overall communication quality. Also the call blocking probability and forced call termination probability is more. To solve these problems, a number of handover methods have been proposed by different scientists. In our previous work we have proposed a fast method for handover named Location Manager Based Handover method for LEO satellite networks where we have use Location Manager (LM) for reducing the scanning time. LM is used to store all the mobility pattern of all the satellites. Here we have analyses the total cost of LMBHO method. To know how this method works, we have compared it to the cost of the standard protocol mobile IP by a set of simulation. Result shows that it can significantly reduce the handover cost.

Keywords
Low Earth Orbit (LEO), Terrestrial Network, Mobile Node (MN), Handover, Location Manager (LM).

1. INTRODUCTION
The demand for global broadband telecommunication services is growing rapidly in next generation mobile satellite systems, and they are expected to provide anytime-anywhere communication services [1][2]. Global coverage is the most important advantage of LEO satellite networks. Low earth orbit satellites rotate around the Earth at altitudes ranging from 500 to 2 000 km. They have important properties like low propagation delay and low equivalent isotropic radiated power (EIRP) requirements for hand-held devices. So LEO satellites make it possible to support real-time interactive multimedia traffic for their users with better quality-of-service (QoS) [3] guarantees.
Quality-of-service parameters include bandwidth, delay, jitter, call blocking probability, call dropping probability etc.

In cellular telecommunications, the term handover or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another. In satellite communications it is the process of transferring satellite control responsibility from one earth station to another without loss or interruption of service.

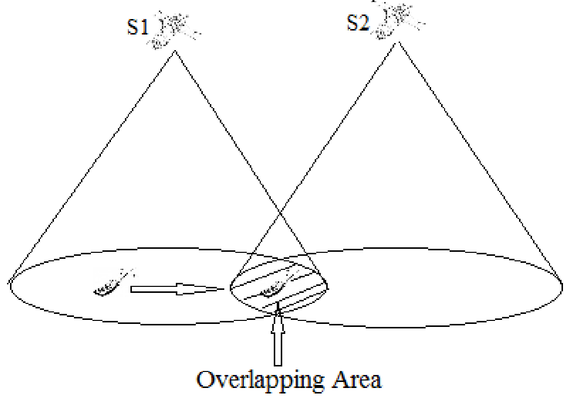

Figure: 1 Handover Occurrence

A Hard Handover is one in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus the connection to the source is broken before or 'as' the connection to the target is made—for this reason such handovers are also known as break-before-make. Hard handovers are intended to be instantaneous in order to minimize the disruption to the call. When the mobile is between base stations, then the mobile can switch with any of the base stations, so the base stations bounce the link with the mobile back and forth. [4]
A Soft Handover is one in which the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the source is broken, hence this handover is called make-before-break. The interval, during which the two connections are used in parallel, may be brief or substantial. Soft handovers may involve using connections to more than two cells: connections to three, four or more cells can be maintained by one phone at the same time. The latter is more advantageous, and when such combining is performed both in the downlink (forward link) and the uplink (reverse link) the handover is termed as softer. Softer handovers are possible when the cells involved in the handovers have a single cell site [5].

Scanning: When a mobile station is moving away from its current satellite, it initiates the handoff process when the received signal strength and signal-to-noise-ratio have decreased below the threshold level. The MN now begins the scanning to find new satellite. It can either opt for a passive scan (where it listens for beacon frames periodically sent out by satellites) or chose a faster active scanning mechanism wherein it regularly sends out probe request frames and waits for responses for T_{MIN} (min Channel Time) and continues scanning until T_{MAX} (max Channel Time) if at least one response has been heard within T_{MIN}. Thus, $n*T_{MIN} \leq$ time to scan n channels $\leq n*T_{MAX}$. The information gathered is then processed so that the MN can decide which Satellite to join next. The total time required until this point constitutes 90% of the handoff delay [6][7].

Authentication: Authentication is necessary to associate the link with the new satellite. Authentication must either immediately proceed to association or must immediately follow a channel scan cycle. In pre-authentication schemes, the MN authenticates with the new satellite immediately after the scan cycle finishes.[8][9]

Re-Association: Re-association is a process for transferring associations from old satellite to new one. Once the MN has been authenticated with the new satellite, re-association can be started. Previous works has shown re-association delay to be around 1-2 ms. The range of scanning delay is given by:-
N × Tmin _ Tscan _ N × Tmax
Where N is the total number of channels according to the spectrum released by a country, Tmin is Min Channel Time, Tscan is the total measured scanning delay, and Tmax is Max Channel Time. Here we focus on reducing the scanning delay by minimizing the total number of scans performed.[10],[11].
In this paper we have proposed a new handover technique which reduces the handover latency. Here we used the LM which is a database manager and supports the management of whole system.
The paper is organised as follow: in the second section we have described the related works on handover management. In the third section we have described the details of LMBHO. In the forth section the simulation results of both our method and standard methods. In the next section we conclude the whole paper and finally a future work is mention regarding this paper in section six.

2. RELATED WORK

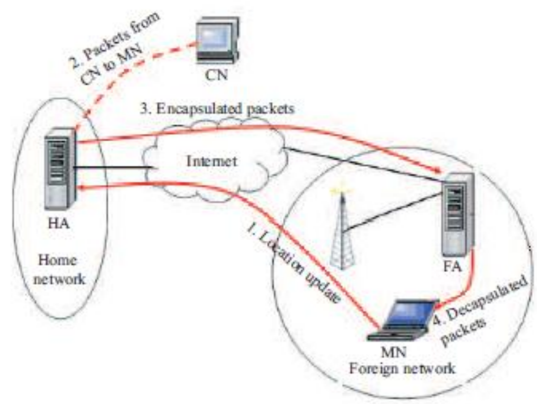

Figure 2: Handover Flow of Mobile IP

The most widely used protocol for handover in satellite is MIP [12]. It is proposed by The Internet engineering task force (IETF) to handle mobility of internet hosts for mobile data communications. MIP is based over the concept of Home Agent (HA) and Foreign Agent (FA) for delivering of packets from one MN to CN. It is basically completed by four steps.

i) When handover begins MN registers itself in FA and waits for allocation of channels in FA and updates its location in HA directory.
ii) The packets are sent to HA and HA encapsulate it.
iii) Encapsulated packets are sent to The FA.
iv) FA decapsulate those packets and sent it to MN.

The main drawback of this protocol is

- High handover latency
- High packet lost rate
- Insufficient routing path
- Conflicts with network security solution

Another method is Seamless handover management scheme (SeaHO-LEO) [13], [14] proposed by Aysegul et al in 2006.
It reduces packet loss and handover latency. It is describes as follows

A. Calculate a new IP
B. Send handover preparation request to current satellite
C. Start to use new IP to send data packets
D. CN starts to use new satellite

SeaHO-LEO provides efficient utilization of network bandwidth because of the absence of tunnelling and also does not need any change in existing internet infrastructure.
The main disadvantage of this process is *high messaging traffic*.

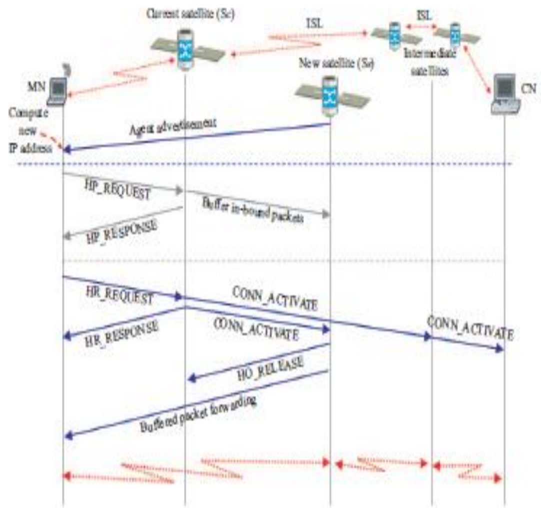

Figure 3: Signalling Flow of SeaHO-LEO

Another method to remove high messaging traffic is Pattern based handover management (PatHO-LEO) [13],[14]. It describes as follows

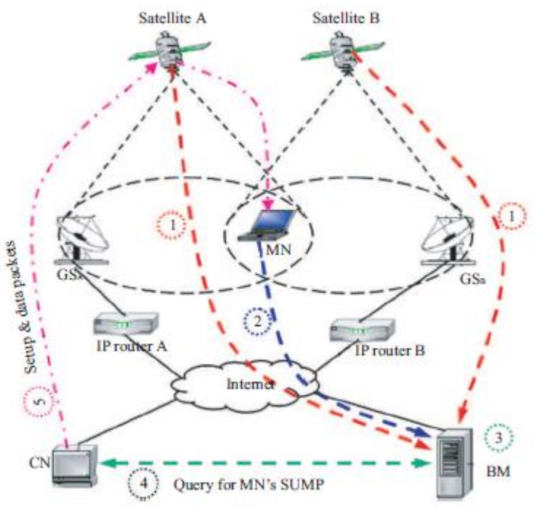

Figure 4: Handover scenario in PatHO-LEO

- ✓ Satellite register to BM.
- ✓ MN registers to BM.
- ✓ BM establishes the satellite and user mobility pattern (SMUP) table.
- ✓ CN and BM establish connection.
- ✓ CN sends data packets to MN.

But the main drawback of PatHO-LEO is that

i) Every user should have a specific mobility pattern in a specific period of time. A user can have more than one mobility pattern. But when it violets its mobility pattern the handover process will be either in SeaHO-LEO or MIP.

ii) The no of user who do not have a specific mobility pattern in a week is increasing day by day like salesman, LIC worker who have to go different place at different time in a week.

Also there are other mobility management protocols such as Transport layer seamless handoff schemes for space networks (TraSH-SN) [15], paging in mobile IP (P-MIP) [16], and cellular IP [17]. These methods will not be covered in this paper.

In our previous work we have proposed a new method based on Location Manager named Location Manager Based handover method (LMBHO).

In our proposed method we assume that the MN is equipped with GPS so that the positions of the MN can be found at the time of handover.

Now we will define 3 levels for handover based on the received signal strength and signal-to-noise ratio (SS & S/N).

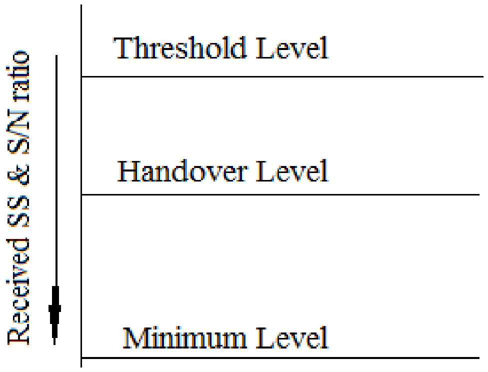

Fig 5 levels for handover

A. Threshold Level: Whenever the received (S/N) crosses this level the LMBHO method begins.

B. Handover level: whenever the received SS & S/N crosses this level, the handover preparation step is completed and the handover completion step begins.

C. Minimum level: Whenever the received SS and S/N crosses this level the connection is lost. So this is the minimum level for the connection. The handover must be completed before MN crosses this level.

The LMBHO has the following steps

A. Handover Preparation: In this step the necessary preparation for handover is done. This step is completed before MN crosses the Handover level.

B. Handover Completion: In this step the handover is completed using the new satellite. This step must be completed before received SS and S/N crosses the minimum level.

Initial Set Up: Initially all the positions of the satellite with corresponding time are saved in location manager. All the satellite can use this database form LM whenever the handover begins.

Step 1: The handover generally begins when the MN enters the overlapping coverage area of the two adjacent satellites. But it is not possible for MN to find whether it has moved to this overlapped area. So MN continuously checks the received SS & S/N crosses the threshold level of handover. If it crossed then the handover begins.

Step 2: Now as soon as MN finds that the received SS & S/N crosses the threshold level, it sends an EQ_MSG to LM enquiring about the name of satellites covers that region at that time. EQ_MSG contains the position of MN at that time and the IP address of the current satellite.

Step 3: After receiving the EQ_MSG, LM finds the list of satellites available at that time form its database other than current satellite. Then LM responses with a RS_MSG which contains the list IP addresses of the satellites available at that time.

Step 4: After receiving the RS_MSG, MN sends a QS_MSG to all the satellites in the RS_MSG to know the signal strength and the channel capacity of that satellites at that time.

Step 5: As soon as any satellite receives QS_MSG it replies back to that MN with RP_MSG which contains the signal strength and channel capacity at that time.

In the meantime MN continuously checks if the received SS & S/N crosses the handover level. If it crosses then it starts the handover completion steps which are described as follows.

Step 6: Now MN selects the best satellite available on the basis of Quality of Service (QOS) parameters which are

- Maximum service time
- Maximum number of free channels
- Minimum distance

It also includes the signal strength and the channel capacity of the satellites. A specific algorithm has to be developed for selection (In our future work).

Step 7: Now MN sends a handover request HO_REQ to the new satellite which contains the IP address of the MN, IP address of the current satellite and IP address of the adjacent satellite.

Step 8: As soon as the new satellite receives the HO_REQ it sends a connection release message CONN_REL to the current satellite to release the connection from MN. It simultaneously sends a connection activate message CONN_ACT to the adjacent satellite which contains the IP address of the current satellite.

Step 9: whenever adjacent satellite receives the CONN_ACT message it sends the next data to the new satellite and the new satellite forwards it to the MN. Meanwhile the current satellite releases the connection as soon as it receives the CONN_REL message. Now the connection is made by the new path and the handover is completed.

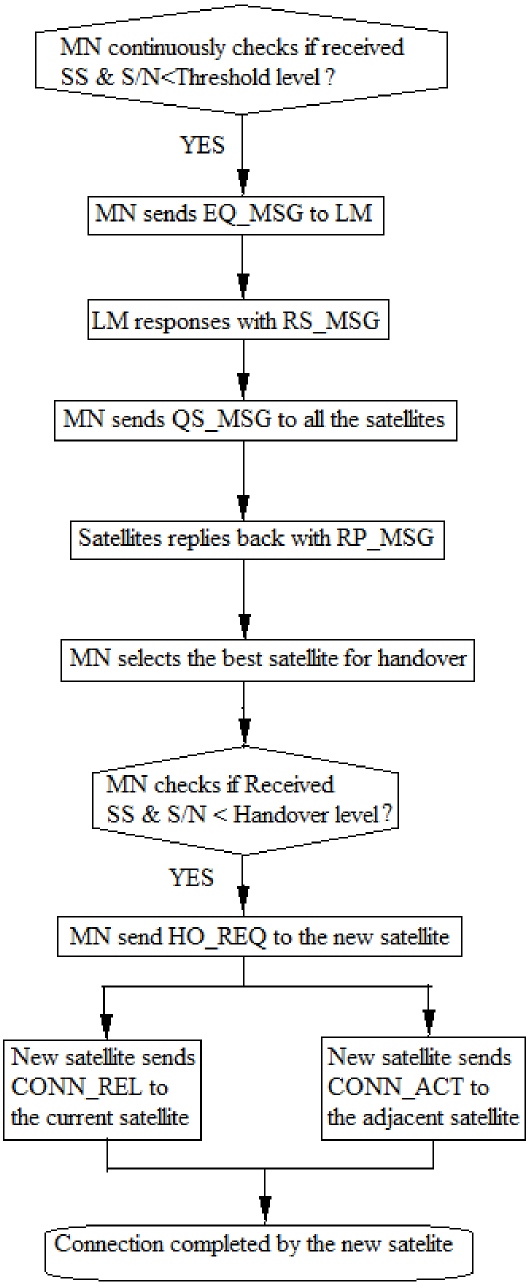

Fig: 6 flow chart of LMBHO method

The advantages of this proposed method are

A. This method reduces the scanning time for searching a new satellite. Actually the scanning time equal to zero as no scanning is required for finding the new satellite. The list of available satellites can be found by sending only an EQ_MSG to LM.

B. The high messaging traffic has been reduced in this method

C. As this method uses only the patterns of satellites which is not subjected to change so this method can be used everywhere unlike PatHO-LEO which cannot be used where user does not have any specific mobility pattern.

D. This method can be used for static CN as well as movable another MN. The signal flow can be one sided or both sided.

3. PROPOSED WORK

In our previous work we have discussed the LMBHO method and shown how it can reduce handover latency and call blocking probability.

Here we will analysis the cost of this LMBHO method and compare it with other standard methods like MIP.

Mobility Management Cost Definition

In [12] the mobility management cost is evaluated as the product of generated control message size, M and the number of hopes, H, required to deliver the message. If we apply such definition into the paging cost, it will be proportional with the number of receivers. Taking into account the broadcasting capabilities of satellites, however, the cost is also simply a product of the message size and the number of travelled hops.

$$Cost=M.H \tag{1}$$

Costs of different Mobility management events:

The following defines the cost required for each mobility management event; binding update, local forwarding and paging

For each case, the Control messages generated are assumed to be equally sized (M) in all the four events. The number of control messages that are generated upon a handover occurrence between mobile nodes and the corresponding ARs, is assumed to be same for MIP and our proposed method. Thus we can neglect the number of control message in the cost evaluation.

1. *Binding Update Cost:* Let $H_{MN,LD}$ denote the number of hops between a mobile node and the Location Directory. The cost for binding update procedure can be expressed as:

$$M.H_{MN,LD}$$

2. *Local Forwarding Cost:* Denoting the number of hops between two adjacent satellites as $H_{AR,AR}$ the local forwarding cost is shown as follows:

$$M \cdot H_{AR,AR}$$

Management Cost of MIP and our proposed method

The costs of Mobile IP and our proposed method are as follows

A. Mobile IP: The cost of MIP is the product of binding update cost and rate of handover occurrence. The local forwarding, paging and GPS are not used here. So the MIP management cost, $C_{MIP}(t)$ can be expressed as

$$C_{MIP}(t)= M.H_{MN,LD}.R_{HO}(t) \tag{2}$$

Where the rate of handover occurrence, $R_{HO}(t)$, is:

$$R_{HO}(t)=V_{sat}.L_{sat}\int_{Vsat(t-t\Delta)}^{Vsat.t} DL(Vsat.t)dt \tag{3}$$

Where, V_{sat} and L_{sat} denote the ground speed of satellite and the coverage boundary length, respectively. $D_L(V_{sat}.t)$ denote the linear density of nodes on the coverage boundary at time t.

B. Proposed Method: In our proposed method the total no of messages exchanged between LM and MN during every handover is 2. So the message transfer cost between LM to MN is

$$C_{LM,MN} = 2*M*H_{LM,MN} \tag{4}$$

The message exchanged between the satellites and the MN is $2*n + 3$ where n is the number of available satellites. So the cost for message transfer between Satellites and MN is

$C_{Sat,MN} = (2*n + 3)*M*H_{Sat,MN}$ (5)

So total cost for messaging is

$C_{MSG} = C_{LM,MN} + C_{Sat,MN}$ (6)

So the total cost is

$$C_{TOT} = (C_{MSG} + M.H_{AR,AR})* R_{HO}(t) = (2*M*H_{LM,MN} + (2*n + 3)*M*H_{Sat,MN}) *R_{HO}(t) \quad (7)$$

The equation 7 represents the total cost for LMBHO.

4. SIMULATION RESULTS

Now we will evaluate the performance in terms of Handover cost of our proposed work LMBHO with Mobile IP. We

The simulation results were run on MATLAB 7.8 in a designed virtual environment.

The simulation environment is created by setting the following parameters.

Satellite coverage area radius	700[km]
Satellite ground Speed	7[km/sec]
Mobile Node speed	17[km/sec](60km/hr)
Number of nodes reside in the coverage area	10^6
Time in footprint	5min

Here we assume that the generated traffic is according to the Poisson distribution function.

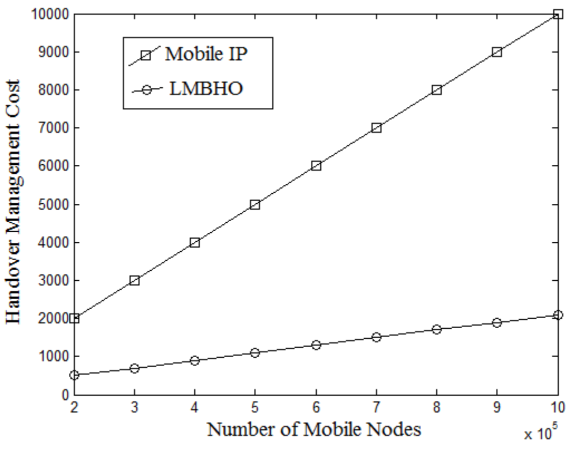

Figure 7 Handover Cost Performances

In the figure 7 we have compared the handover management cost of Mobile IP and LMBHO. Here as we have reduced the searching time for a new satellite so the messages sent over that time for MIP is reduced. As in our previous work we have shown how the handover latency and handover throughput have reduced so the handover management cost reduces.

5. CONCLUSION

In this paper we have analysed the cost of our previously proposed method for handover named LMBHO based on the concept of Location Manager.

We first described the future aspects of LEO satellites and its advantages. Then we defined handover and different types of handover. After that we explained the details of scanning. Then we explained in brief some of the standard protocols MIP, SeaHO_LEO, PatHO_LEO and also mentioned their drawbacks. The details of our proposed method LMBHO is given in the next section and we also mentioned its advantages. Then we have analysed the handover cost of LMBHO and compared it to MIP. The simulation result shows that this LMBHO have cost which is much smaller than MIP.

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6. AUTHORS PROFILE

Debabrata Sarddar (Asst. Professor in Kalyani University) is currently pursuing his PhD at Jadavpur University. He completed his M.Tech in Computer Science & Engineering from DAVV, Indore in 2006, and his B.Tech in Computer Science & Engineering from Regional Engineering College, Durgapur in 2001. His research interest includes wireless and mobile communication. Email: dsarddar@rediffmail.com

Dipsikha Ganguly, currently pursuing B.Tech in Electronics & Communication engineering at B.P.Poddar Institute of Management & Technology under West Bengal University of Technology. Her research interest includes wireless communication & satellite communication. Email: Dips.ganguly@gmail.com

Soumya Das, son of Mr. Subrata Das and Mrs. Swapna Das, currently pursuing his B.Tech Degree in Electronics & communication engg. at Bengal Institute of Technology under West Bengal University of Technology. His research interest includes mobile communication & satellite communication

Suman Kumar Sikdar completed his B.Tech in CSE from Murshidabad College of Engineering & Technology and M.Tech in Computer Science & Engineering from Jadavpur University in 2011. His research interest includes wireless sensor networks and wireless communication systems.
Email: sikdersuman@gmail.com

Sougata Chakraborty is presently an employee of IBM (Kolkata). He has completed his B.Tech in IT from Murshidabad College of Engineering and Technology and M.Tech in Computer Science & Engineering from Jadavpur University in 2011. His research interest includes wireless sensor networks and wireless communication systems.
Email: me.sougata.chakraborty@gmail.com

Kunal Hui is presently an employee of Cognizant (Kolkata). He has completed his B.Tech in Computer Science & Engineering from Murshidabad College of Engineering and Technology (2004-2008) and M.Tech in Computer Science & Engineering from Haldia Institute of Technology (2009-2011). His research interest includes wireless sensor networks and wireless communication systems. Email: kunalhui@gmail.com

Shabnam Bandyopadhyay is presently an employee of Cognizant (Kolkata). She has completed her B.Tech in Electronics and Communication Engineering from Meghnad Saha Institute of Technology and pursuing M.Tech degree in Computer Science & Engineering at Jadavpur University Her research interest includes wireless sensor networks and wireless communication systems. Email: shabnam.msit@gmail.com

Kalyan Kumar Das completed his BE degree in Computer Science and Engineering from REC (NIT), Durgapur in 2002 and M.Tech. in Computer Technology from Jadavpur University in 2011. His research interest includes wireless sensor networks and wireless communication systems. Email: kalyan.biltu@gmail.com

Sujoy Palit completed his M. Tech degree in Computer Science and Engineering from West Bengal University of Technology in 2005. His research interest includes wireless sensor networks and wireless communication systems. Email: sujoy_palit@yahoo.com