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Handover from LTE to VSAT with an Analysis to Provide Optimized Performance in Telemedicine Ambulances

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Abstract

Wireless networks are almost omnipresent in today's world and are also progressing continuously. One of the challenges in these networks when supporting mobility and seamless network connectivity is Vertical Handover (VHO). In our paper we present the scenario of a telemedicine vehicle equipped with video conferencing facilities having Long Term Evolution (LTE) as the primary network and Very Small Aperture Terminal (VSAT) as backup service. One of the considerable issues in a heterogeneous wireless network such as this is the support of VHO. VHO occurs when the user terminal switches from one network to another (in our paper, LTE to VSAT). This needs to be achieved with minimal power consumption maintaining cost efficiency. To accomplish this, we have developed an algorithm to ensure all these criteria work well and numerical analysis is done for the same.

Keywords: LTE, VSAT, eNodeB, MME, SW, GW, UL, DL.

Introduction

To counter the drawbacks in 3G regarding bandwidth, data speed and power consumption, High-Speed Downlink Packet Access (HSDPA), sometimes called 3.5G, evolved. This provided download speeds up to 14Mbps, and as an improvement of this we got HSDPA+ which gives download speed of up to 168Mbps. Later, research on Fourth Generation (4G) technology evolved [1] [2]. Evolution of 4G depicts updating cellular telecommunications not only to move beyond the limitations or problems of 3G, but to raise the Quality of Service (QoS), to increase the bandwidth and to cut the price. High velocity, large net capacity, high usability, multimedia support, personalization and fast/seamless handover across multiple networks are the central characteristics of the fourth generation network. A Heterogeneous Wireless Network [3] [4] has different access technologies for transport, routing and mobility management [5]. Because of these variations, in our application when the ambulance is moving, there is a need to handover the communication channel from one network to another by considering its features and also the user requirements. Channel handover between various networks will be performed by VHO. During handover, there is a need to select the best network.

Handover is the technique of changing the network in order to offer an active session to the user without any interference. A handover technique can be split up into three stages: 1) When to Handover, 2) Radio link transfer and 3) Channel assessment and assignment [6]. Handover decision comprises of the selection of the target point of attachment and the time of the handover [3] [5].

Vertical handover decision (VHD) algorithms help mobile terminals to choose the best network to connect among all the available candidates which, in our paper, are Long Term Evolution (LTE) and Very Small Aperture Terminal (VSAT).

In 4G, we have LTE, using Evolved High-Speed Packet Access (HSPA+) [7], in a faster and less loss while transferring, which in turn helps improving time delay (latency). VSAT is another technology which can be involved in communication. VSAT is very small aperture terminal which has an antenna through which transceiver receives or sends a signal to a satellite [8].

Related Works

A VHO is the process of changing the ongoing network connection from one interface to the other in order to have a seamless connectivity. Various VHD algorithms have been designed recently. The decision algorithms use handover equation or metrics to decide which the best network is. We know that the handover is usually based on the downlink (DL) received signal strength [2] and carrier-to-interference ratio measurements of User Entity (UE) [2] [6]. We can see many interfaces within LTE like x2, s1, s2 etc… [8]. Reviews on handover between LTE and Universal Mobile Telecommunications System (UMTS) as well as from LTE to Wi-Max are available in existing literature [2] [9] [10]. In general, many handover techniques which result in better connectivity have been proposed [9]. From existing literature we can see that handover algorithms are based on few of the parameters like only velocity or cost [9] [10]. But it is also important that QoS be preserved, not just before and after a handover [11], but during the handover as well. Power is also an important parameter to be considered during the handover [2]. Unnecessary handover can weaken the UE battery power [9].

LTE

LTE is being increasingly adopted around the world as the primary cell phone service. One of the reasons for this is the enhancement in user experience while using demanding services like video conferencing or playing advanced games. Handover in LTE [12] refers to the transfer of UE from a source eNodeB (eNB), eNB is like base station or a base transceiver station of any cellular network (3G). The X2 interface enables eNBs to communicate directly between each other which is good for interference management and seamless Handover. While making sure that the Mobile Management Entity (MME) and Serving Gateway (GW) is unaltered. The presence of Internet Protocol (IP) connectivity between the Serving GW and the source eNB, as well as between the Serving GW and the target eNB is assumed. The source eNB frames the UE measure procedures according to the area information. UE sends a MEASUREMENT REPORT by the procedures set by system information, specification, etc. Source eNB makes decisions based on MEASUREMENT REPORT of UE and issues a HANDOVER REQUEST message to the target eNB passing necessary information to prepare handover at the target side. Admission Control may be performed by the target eNB dependent on the received QoS information to increase the likelihood of a successful handover. The target eNB configures the required resources according to the received QoS information. Target eNB provides handover and sends the handover request acknowledgment to the active next serving eNB. Since each eNB has information of next source eNB, the HANDOVER REQUEST ACKNOWLEDGE message will receive a transparent container to be transported to the UE as an RRC (Connection Reconfiguration) message to perform the handover. The UE acquires the RRC message with parameters like C-RNTI, target eNB security algorithm identifiers for the selected security algorithms, and will have other parameters (access parameters SIBs, etc.) And is instructed by the source eNB to perform the VHO.

The source eNB sends the status transfer message to the target eNB to convey the Uplink (UL) receiver status and the DL transmitter status. After receiving a message which includes the mobility control information and accesses the target cell. The target eNB responds with UL allocation and timing advance.

UE sends the RRC Complete message (C-RNTI) to confirm the handover to the target eNB to indicate that the handover procedure is completed for the UE. The target eNB can now begin sending data to the UE. The target eNB delivers a PATH message to MME (MME has been expanded earlier) to inform that the UE has changed cell. The MME delivers an UPDATE USERPLANE REQUEST message to the Serving GW. The Serving GW swaps the DL data path to the target position. The Serving GW addresses one or more "end marker" packets on the old path to the source eNB and then can release any resources towards the source eNB. Serving GW delivers an UPDATE USER PLANE RESPONSE message to MME. MME confirms the message with the path acknowledgment message. By sending UE context release, the target eNB informs success of handover to source eNB and triggers the release of resources by the source eNB. The target eNB delivers this message after the path acknowledgment message is received from the MME. Upon reception of the UE context release message the source eNB can release radio resources associated with the UE context. Any on-going data forward will have continuation.

VSAT

A Very Small Aperture Terminal (VSAT) is a small private earth station that is used to transmit and receive data signals through a satellite and normally come with antenna of diameter less than 2.4m [13].

VSATs are connected by radio frequency (RF) links through a satellite, with an UL from the station to the satellite and downlink (DL) from the satellite to the station. For stable connections across multiple sites worldwide, VSAT networks provide two way satellite broadband links over a wide geographical region. VSAT is ideal for large file transmissions, video communications and remote Internet connectivity. VSAT is the best way to connect distant offices and media vans to supply Internet connectivity for a video transmission [8].

Usually the satellite receives the uplinked carriers from the transmitting earth stations within the field of view of its receiving antenna, amplifies those carriers, translates their frequency to a lower band in order to avoid possible input/output interference, and transmits the amplified carriers to the stations located within the field of view of its transmitting antenna.

It should be noted that the distance from an earth station to the geostationary satellite induces a radio frequency carrier power attenuation of typically 200 dB on both uplink and downlink, and a propagation delay from terminal to terminal (hop delay) of about 0.25s [14]. Usually, one can transmit either one kind of signal or multiple of variant signals. Data and voice are transmitted in a digital format, but video may be analog or digital.

For instance, the relative position of the satellite with respect to the VSAT at a given instant determines the orientation of the VSAT antenna and also the carrier propagation delay value. A VSAT network typically offers a Bit Error Rate (BER) of 10^{-7} [8]. This ensures an acceptable quality for digital voice and video.

Overview of Working of Handover From LTE To VSAT

Assumption:

- Ambulance already has LTE connection.
- Ambulance has a VSAT antenna.
- Ambulance is moving 10 in 1 minute.

Steps:

1. Laptop, which is there in the ambulance, is initially connected to LTE as shown in the figure (with red line) which means the BS1 is connected to the laptop, i.e. the laptop is in the range of BS1.
2. MME in the laptop searches for existing networks, just like Bluetooth, you will get the list of the entire existing network.
3. As long as the LTE tower is there, the laptop connects to the LTE base stations, and each base station receives the information of neighboring base stations.
4. When the ambulance is out of reach of any base station of LTE, then there

may be a chance that communication may become cut off. So, we handover to VSAT for further communication.

5. We keep into account of all the parameters like cost, bandwidth, etc.., to have a good communication by performing the handover (LTE to VSAT).

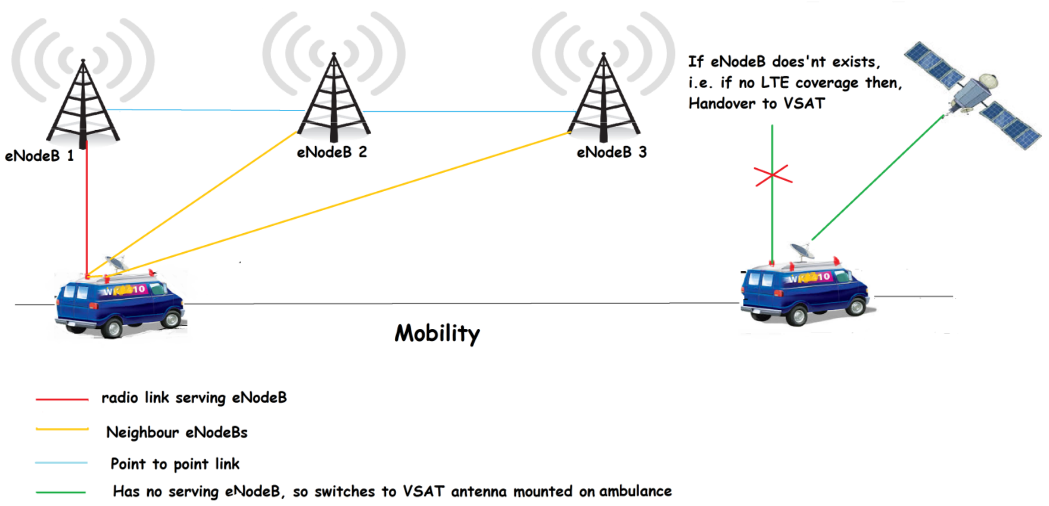

Figure 1: Architecture Diagram

Main Contribution

Algorithm

In our algorithm, there are 3 main steps:

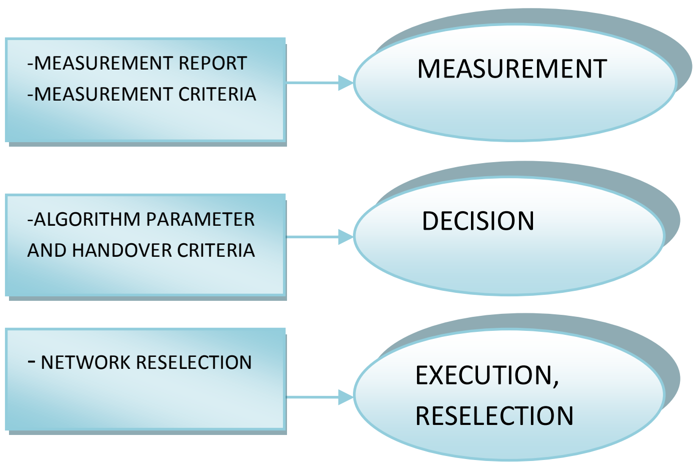

Figure 2: Steps in the algorithm

Step 1: **Measurement**

Measurement Report

User Entity (UE) measures three parameters on reference signal,

1. Received Strength Signal Indicator (RSSI) [15] measures the average power observed in OFDM symbols containing reference symbols. This includes power from co-channel serving, non-serving cells, and thermal noise and so on…
2. Reference Signal Received Power (RSRP) is the average received power of all resource components. Its typical ranges are around -44 to -130dbm. RSRP is measured by (RSSI-10*log (12*N)), where N is the number of physical reference blocks over which RSSI is measured [7] [15].
3. Reference Signal Receive Quality (RSRQ) [15] indicates the quality of the received reference signal. It is defined as (N*RSRP) /E-UTRA Carrier RSSI.

Using these parameters and details generated at 1second in Universal Radio Communication Tester, the handover trigger decision can be made when the RSSI of the target cell is greater than the RSSI of the current cell i.e.,

If and only if

$$RSRP_{target\ cell} > RSRP_{current\ cell} + h \quad \textbf{(2)}$$

$$RSRQ_{target\ cell} >= RSRQ_{current\ cell} + h \quad \textbf{(3)}$$

Where, $RSRP_{target\ cell}$ and $RSRP_{current\ cell}$ RSRP of the target cell (next serving cell) and the current Reference signal received power, $RSRQ_{target\ cell}$ and $RSRQ_{current\ cell}$ are the RSRQ of the target cell (next serving cell) and the current Reference signal received quality, h is the hysteresis.

Measurement Criteria

Mobility estimation is done. For this we set a decision period to be T = {1, 2, 3… N} where N is the time (in seconds) at which the connection terminates. Based on previous measurement using GAUSS_MARKOV theorem we can consider the velocity as a scalar since our ambulance is moving on the road. When the UE moves faster, the probability that the connection will be shed during the vertical handover process increases, the UE's connection may be cut down [16]. To avoid this we consider, as in Equation 4, that the probability from v to v_i can be,

$$P\,(v_{i+1}/v_i) = \frac{[\left(l-\frac{l_1}{t}=v_i\right)\&\left(l-\frac{l_1}{t}=v_{i+1}\right)]}{\left(l-\frac{l_k}{T}=v_i\right)} \quad \textbf{(4)}$$

Where, l and v_i are the location and velocity in 2 dimensional movement.

When the vehicle turns (left or right) the probability will change as in Equation 5:

$$P_{i,i+1}=\{P(v_{i+1}/v_i) \text{ if } lk = l+tv_i,\ 0 \text{ if } lk \mathrel{!=} l+tv_i\} \quad \textbf{(5)}$$

Step 2: **Handover Decision**

Ho decision is taken at by the UE when the threshold value of LTE is greater than 1 and checks for the threshold value of VSAT i.e.

Threshold value for LTE,

$$\text{Threshold} = \sum_{k=0}^{n} \begin{pmatrix} \sum Bw + \sum (w) \\ + \sum (C + a) + h \end{pmatrix} \quad \textbf{(6)}$$

Where, Bw= Bandwidth i.e. {10, 20… $BW_{max}\}$ BW_{max} is the maximum bandwidth each network provide, network parameter, n is available networks, h is deciding when to handover i.e. hysteresis, w is the quality based on frame duration and signal speed and C is the cost per 1kbps i.e, C= (BW/c) /max {BW_{max}, $C_{max}\}$, where, c is the access cost of any of two networks, BW_{max}, Cmax is the maximum cost and bandwidth each network can support.

If Threshold > 5, handover to other network and

If Threshold < 5, remain in the same network.

Considering the eNodeB coverage to be split into 3 circles or rings of different radius, than h, the hysteresis can be calculated based on when UE and the base station eNodeB use different distances to change to different hysteresis value,

$$h=\max\{c\,[1-(d/R)],\, 0\} \quad \textbf{(7)}$$

Where, d is the distance between the UE and the eNodeB, R is the radius of the eNodeB coverage; c and k are the scaling factors for the hysteresis.

When the distance between the UE and the Qth eNodeB is $d_{i,Q}$, the R_i is the RSSI of the UE from the Qth eNodeB can be obtained. The received power of the UE in the ring of the eNodeB is,

$$P= P_t*(d/d_0) \quad \textbf{(8)}$$

Where the transmitted power is p_t and d_0 varies accordingly in meters (m).

Then, when the UE is farer from eNB, the received bandwidth of UE can be,

$$B=BW*(R/P) \quad \textbf{(9)}$$

Step 3: Execution And Reselection

On the flow, when the RSSI value becomes less than the threshold of LTE, then the RSSI value is checked with the threshold of VSAT.

When changing from VSAT network to the nth AP in LTE the handover.

$$\sum Bw^1 >VSAT+\sum Bw+h \quad \textbf{(10)}$$

Where, Bw^1 is the bandwidth by the UE from nth APs after handover, Bw is the UE from nth AP before the handover. h is the hysteresis value, VSAT bandwidth obtained by UE from VSAT before the handover. n ranges from 1to Q, Q is the total number of LTE APs.

$$w^1=Bw*U_Q \quad \textbf{(11)}$$

Where, U_Q is the UE in the AP before the handover.

When the UE moves from VSAT network to nth eNodeB i.e., there is a presence of LTE then hysteresis H1 can be decided by position by,

$$H1=100\{c(1-(Bta\,/Btb)),0\} \quad \textbf{(12)}$$

Where, $B_{tb}=\sum BW$ of LTE and
$B_{ta}=\sum BW+VSAT$ for VSAT
Now, when UE moves from Qth eNodeB in LTE to VSAT network, the hysteresis can be decided by the position by,

$$H2=100\{c(1-(B_{ta2}/B_{tb2})),0\} \quad \textbf{(13)}$$

Where, $B_{tb2}=\sum BW+VSAT$ and $B_{ta2}=\sum BW + BW^{1}$

Numerical Result

Table 1: Comparison of LTE and VSAT features.

Parameters	**Description of LTE**	**Description of VSAT**
Mobility	40km/hr to 350km/hr	20km/hr to 50 km/hr
Channel Bandwidth (MHz)	1, 4, 3, 5, 10, 15, 20	0.064, 0.1, 1, 2, 4
Multiple Access Schemes	UL: SC-FDMA (Single Carrier Frequency Division Multiple Access) supports 50MBps+ (20MHz spectrum)	The Ku-band is typically in the uplink frequencies of 13.75 to 14.5 GHz.
	DL: OFDMA (Orthogonal Frequency Division Multiple Access) supports 100MBps+ (20MHz spectrum)	The Ku-band downlink frequencies of 10.7 to 12.75 GHz and
Peak data rate in LTE	UL: 75Mbps (20MHz bandwidth)	UL:64kbps
	DL: 150Mbps (UE Category 4, 2x2 MIMO, 20 MHz bandwidth)	DL:55kbps
Coverage	5-100km with slight degradation after 30km	10,000 to 15000km due to no line of sight there may be no coverage.
Latency	End-user latency < 10ms	Between 600ms to 800ms

Considering above values, we have analyzed the performance of the above algorithm, considering LTE coverage to be split into four circles, the outermost to be of a diameter 100km and bandwidth of 25Mbps, similarly another inner circle of diameter 75, 50 and 25Kms with bandwidth of 50, 75, 100Mbps, as shown in fig 2.

Considering the report generated by RSRP and RSRQ at each millisecond and the mobility of the vehicle to be at 40Km, priority being moved on the road.

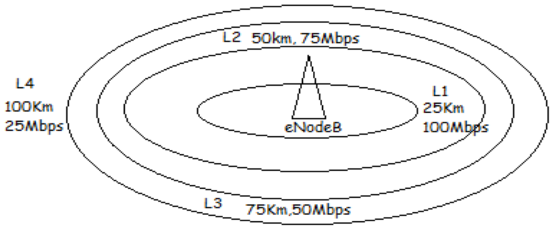

Figure 3: Coverage of LTE

Considering the report generated by RSRP and RSRQ at each millisecond and the mobility of the vehicle to be at 40Km, priority being moved on the road. When RSRQ=34 and RSRP=97 then the state is called handover decision. The below plotted graph shows, how the RSRP and RSRQ value increases as the time increases.

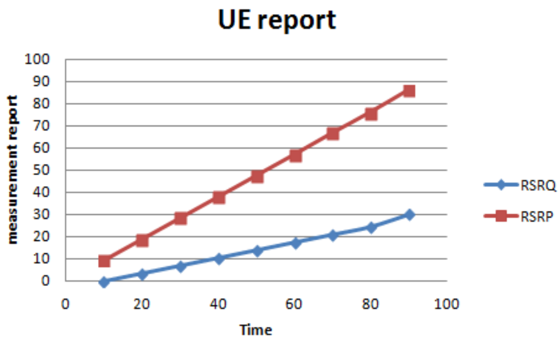

Figure 4: UE Report based on RSRP & RSRQ

As demonstrated in the Fig 4, that at every 90ms there is a need to check whether handover is required or not. We have considered that vehicle is moving in a straight line on the road. Thus it has a line of sight from VSAT to satellite. After the values of RSRP and RSRQ are generated, the handover decision part of the algorithm needs to be executed every 90ms and the bandwidth and distance between UE and eNB are also calculated. As the distance increases the bandwidth decreases (in Fig 5).

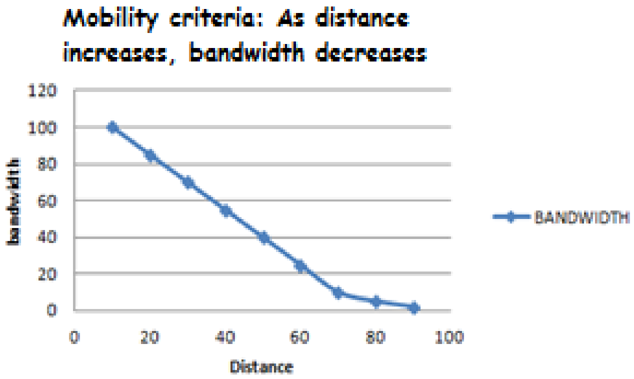

Figure 5: Mobility Criteria

So when the threshold value as to our analysis, if it's greater than 5 then handover to VSAT if it is less than 5 then remain the same network.

Conclusion

We have proposed a generalized VHO algorithm to make more efficiently by considering the cost, network type, QoS. The VHO mainly focuses on the handover from LTE to VSAT for video conferencing in ambulance based on handover parameters. We can also send the details of the patients like ECG, lung pulse, heart beat rate, etc. In order to evaluate the performance, we analyze that the proposed algorithm performs better than the other existing VHO algorithm. From this approach, we hope at least one life is saved.

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