LTE WiFi Offload

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Abstract

The technology evolution of radio access networks is limited by the laws of physics, and significant growth in radio frequency (RF) efficiency can no longer be expected. The combination of Smartphones such as iPhones, netbooks and 3G/4G mobile networks are rapidly growing in very large numbers and as a result, this has created an exceptional demand for ubiquitous connectivity and quality of rich digital content and applications. To meet the requirements of future data-rich applications and terminals with improved multimedia, future wireless networks are expected to combine multiple access technologies. With an increasing number of mobile devices featuring Wi-Fi capabilities and Wi-Fi access becoming more widely available in homes, enterprises and retail locations, Wi-Fi offload is emerging as an attractive option for network operators.

The goal of this project is to address solutions for WiFi offloading in LTE networks when performance needs exceeds the capability of the LTE access. Novel offloading algorithms are proposed and implemented in CEWiT's 4G test bed, that decides when to move flow(s) between LTE and WiFi access networks.

Contents

1 Introduction to LTE-WiFi offloading

1.1 Long Term Evolution

LTE is a standard for wireless data communications technology. LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication System (UMTS), which in turn evolved from the Global System for Mobile Communications (GSM). The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. A further goal was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture. It replaces the WCDMA transmission scheme of UMTS so that OFDMA (Orthogonal Frequency-Division Multiple Access) is used for downlink while SC-FDMA (Single-carrier FDMA) is used for uplink traffic. A rapid increase of mobile data usage and emergence of new applications such as MMOG (Multimedia Online Gaming), mobile TV, Web 2.0, streaming contents have motivated the 3rd Generation Partnership Project (3GPP) to work on the Long-Term Evolution (LTE) on the way towards fourth-generation mobile.

1.2 Mobile Data Offloading and its necessity

Mobile data offloading is the use of complementary network technologies for delivering data originally targeted for cellular networks. Rules triggering the mobile offloading action can be set by either an end-user (mobile subscriber) or an operator. The code operating on the rules resides in an end-user device, in a server, or is divided between the two. End users do data offloading for data service cost control and the availability of higher bandwidth. Operators do it to ease congestion of cellular networks. The main complementary network technologies used for mobile data offloading are Wi-Fi, femtocell and Integrated Mobile Broadcast.

Increasing need for offloading solutions is caused by the explosion of Internet data traffic, especially the growing portion of traffic going through mobile networks. This has been enabled by smartphone devices possessing Wi-Fi capabilities together with large screens and different Internet applications, from browsers to video and audio streaming applications. In addition to smart phones laptops with 3G access capabilities are also seen as a major source of mobile data traffic.

1.3 Advantage of WiFi

- Wi-Fi networks operate in the unlicensed 2.4 Ghz radio bands, with an 11 Mbps (802.11b) or 54 Mbps (802.11a) data rate, respectively.[4]
- Qos and security support is comparable to LTE networks.[1]

- A vast majority of laptops shipped today have a built-in Wi-Fi interface. Wi-Fi interfaces are now also being built into a variety of devices, including personal data assistants (PDAs), cordless phones, cellular phones, cameras, and media players.
- It offers communication in a small geographical location at a very high speed.
- Research shows that around 80% of the mentioned data traffic happens when subscribe is stationary (i.e. not mobile) e.g. with-in a building, house, office compound, malls etc. Thus mobility is not even required here.[5]

Thus Wi-Fi becomes an obvious choice for network operators. It can help improve cellular coverage and increase capacity through spectrum reuse in areas where most of the data traffic is being generated e.g. in a building. Thus cellular network shall be used for high QoS intensive traffic as well as mobility requirements e.g. VOIP, where as Wi-FI shall be used for low QoS data traffic e.g. downloads, web surfing etc.

1.4 Challenges to Wifi Offload

Existing Wi-Fi networks offer following challenges to LTE <-> Wi-Fi offload:

- Un-Trusted access points (those which are not owned by cellular service providers) don't provide secure connection to EPC
- Existing APs don't provide a means to authenticate with core network using cellular network credentials e.g. SIM (GSM), USIM (LTE) etc.
- Existing APs don't provide a means to obtain same IP Address (as obtained via LTE network) via Wi-Fi network
- Existing Wi-Fi networks don't facilitate a means to UE by which they can select an AP which can provide them connectivity to core network of their server provider.

2 Project Statement

To design an offloading algorithm which decides if Wifi network is good enough to provide the user better bandwidth compared to LTE network and make Wifi an alternative mode of data communication for the user.

First part is to arrive at an offloading algorithm which tries to predict Wifi bandwidth based on various measured parameters of Wifi like RCPI, number of active stations, load on the network and to verify the precision of this algorithm. The parameters are measured by the client and sent to the eNb which decides if Wifi is better than LTE or not.

Second part is to add software modules to server and client side and stream a video from server to client. Wifi parameters are sent by client and server collects them and streams data through LTE or Wifi depending on the output of the algorithm.

3 Wifi parameters

3.1 Received Channel Power Indicator (RCPI)

It is the indication of the total channel power (signal, noise, and interference) of a received frame measured on the channel and at the antenna connector used to receive the frame.

$$RCPI = Int(Power_{dBm} + 110)\times 2, 0dbm > Power_{dBm} > -110dBm$$

It is a 8-bit value which indicates the strength of the signal and it is a monotonically increasing function of signl strength. RCPI is an 802.11 measure of the received RF power in a selected channel over the preamble and the entire received frame. It is an important parameter which decides the throughput of Wifi.

Signal Strength in dBm	RCPI	Throughput in MBits/s
-28	164	42.8
-38	144	38.7
-52	116	31.9
-66	88	24.3
-82	56	5.5
-95	30	0

Table: RCPI vs Throughput

The values in the table are measured by a tool called iperf which calculates the maximum bandwidth available. The server was connected through Wifi and the client through LAN so that the bottleneck will be the downlink bandwidth provided by Wifi to the server. (Server receives data from client to find the maximum possible bandwidth) It was ensured that only one station was connected which taking these measurements.

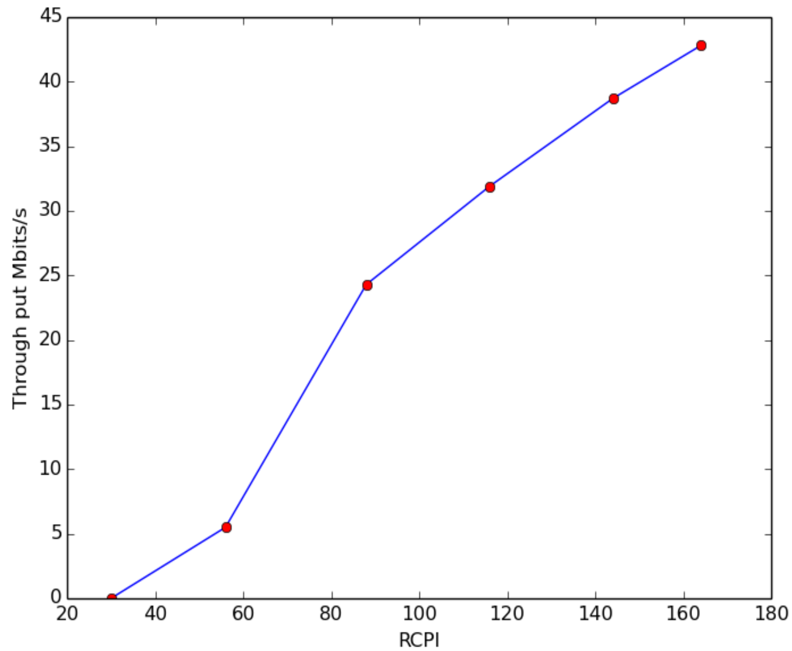

Figure 1: Throughput vs RCPI

3.2 Noise and Interference

The souces of noise are microwave ovens, cordless phone , wireless speakers etc. Due the absence of these sources the only source of noise is thermal noise of Wifi card which is also the minimum threshold to detect a wifi signal of a particular Wifi card. In the case of Atheros chipset AR9485 which is used here, the thermal noise is -95dBm.

Interference produced due to other Access Points is negligible due to carrier sensing. Carrier sense multiple access (CSMA) is a probabilistic media access control (MAC) protocol in which a node verifies the absence of other traffic before transmitting on a shared transmission medium. A transmitter uses feedback from a receiver to determine whether another transmission is in progress before initiating a transmission. That is, it tries to detect the presence of a carrier wave from another station before attempting to transmit. If a carrier is sensed, the station waits for the transmission in progress to finish before initiating its own transmission. In other words, CSMA is based on the principle "sense before transmit" or "listen before talk". Since noise is fixed and interference is negligible Signal-to-interference-plus-noise ratio (SINR) becomes a function of Signal strength alone.

3.3 Number of active stations

It is the number of active stations associated with an AP and is currently using its service. Number of active stations affects the effective bandwidth available during downlink. Since Wifi is half duplex they also affect the time available during uplink.

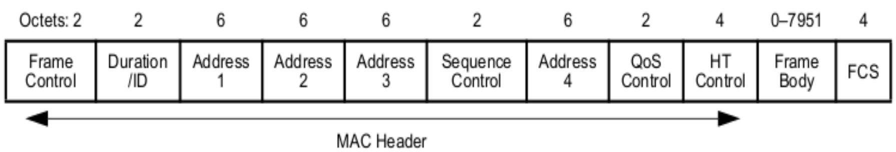

Figure 2: Packet format

As per the IEEE 802.11 standard [3] Wifi packets have a particular format. MAC header is not encrypted. So these frames can be captured and the details in MAC header can be read. So after capturing these packets, the transmitter address is checked to see from which access point the packet is coming from. Then the destination address is checked and the number of users count is incremented if the user is not deteced already. Based on this method the number of active stations associated with the AP is measured.

3.4 Downlink load on the network

Load on the network is the amount of bandwidth occupied on the network. It is the amount of data sent by an AP in the downlink. It will help in predicting the effective time share percentage available if the client associates with that AP. Here we measure only the downlink load and it can be easily extended to measure uplink load also. But uplink load measurement might not be accurate due to hidden substation problem.

3.4.1 Measurement

The captured packets are read and the transmitter address is checked and then the size of the packet is measured. By capturing packets over a certain period time and by measuring their size the load on the network is measured. This algorithm measures only the load created by data packets and ignores the load due to control and management packets but it can be extended measure the load due to these also.

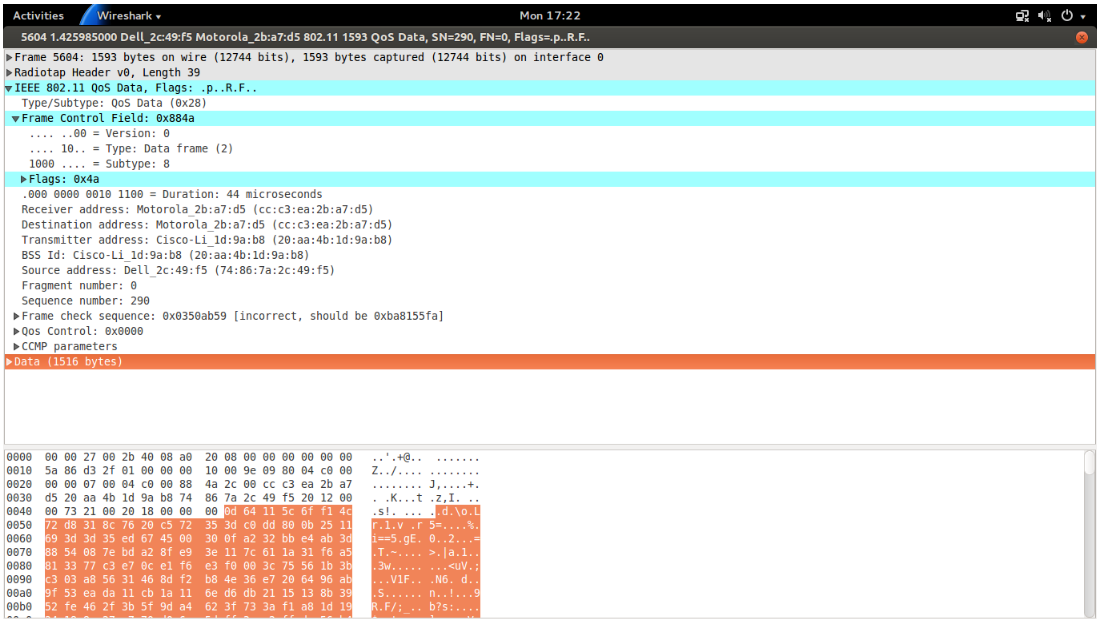

Figure 3: Sample Packet

3.4.2 Verification

A video was streamed at a set rate in an unloaded AP and the load was measured at layer 2 including MAC header. They produced similar values which confirmed that this method is valid.

Set value (kbps) (video+audio @ application level)	Observed (kbps)	VLC contribution (kbps)
256+0	304	256
128+128	328	256
256+128	432	384
512+128	712	640
1024+128	1160	1152
2048+128	2312	2176

4 Experimental Setup

This is the LTE test bed. Wifi cards were attached to both eNb and client side. Software modules were added to both eNb and client side. Client scans Wifi and measures the parameters and sends it to eNb. It creates UDP socket and sends the data as a packet over this. [2]

Figure 4: CEWiT's LTE Test Bed

The software added on the server side receives the data sent by client and decides whether to stream the video through Wifi or through LTE based on the offloading algorithm proposed in the next section. Again it does this by creating an UDP socket and sending the data through this socket.

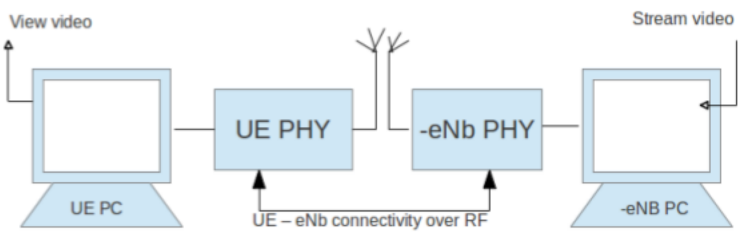

Figure 5: Block Diagram of the LTE Test Bed

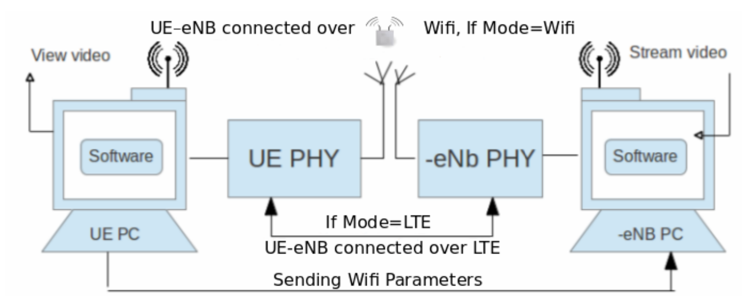

Figure 6: Enhancement to the Test Bed

5 Assumptions used:

The assumptions made are

- No other Acess Point operates in the same channel

- The souces of noise like microwave ovens, cordless phone , wireless speakers etc. are absent and the only source of noise is thermal noise
- The amount of data transfer in uplink is negligible
- Data transfer from management and control frames is negligible
- Stations are randomly located around the Access Point

6 Offloading Algorithm

The following algorithm is proposed for LTE-Wifi offloading.

- Select LTE if the maximum throughput possible for a given RCPI (caculated from RCPI vs Throughput graph) is less than LTE throughput.
- If the above condition is false then check if the throughput for the least possible average time share is better than LTE throughput.
  - This is found by first calculating number of dominant users N which is assumed to be number of users whose downlink load is at least one-tenth of the maximum load among all stations.
  - Least possible average time share expected time share is 1/(N+1) for every 1 second.
  - Expected throughput is assumed to be the product of throughput (if only one station is present) multiplied by time share ratio.
- If yes select Wifi.
- Else, we find the average expected time share, if the client associates with the AP, based on the load.
  - Here we assume that all the stations are situated at a distance which produces average bit rate (The RCPI at which the average bit rate will be realised is assumed to be -82dBm).
  - The time share is found by subtracting the time taken for a station at the average RCPI for the measured load.
  - Expected throughput is found by multiplying the time share with throughput based on RCPI (if only one station is present).
- If the throughput for this case is more than expected LTE's throughput select Wifi else select LTE.
- Repeat this procedure every $\Delta_t$seconds.

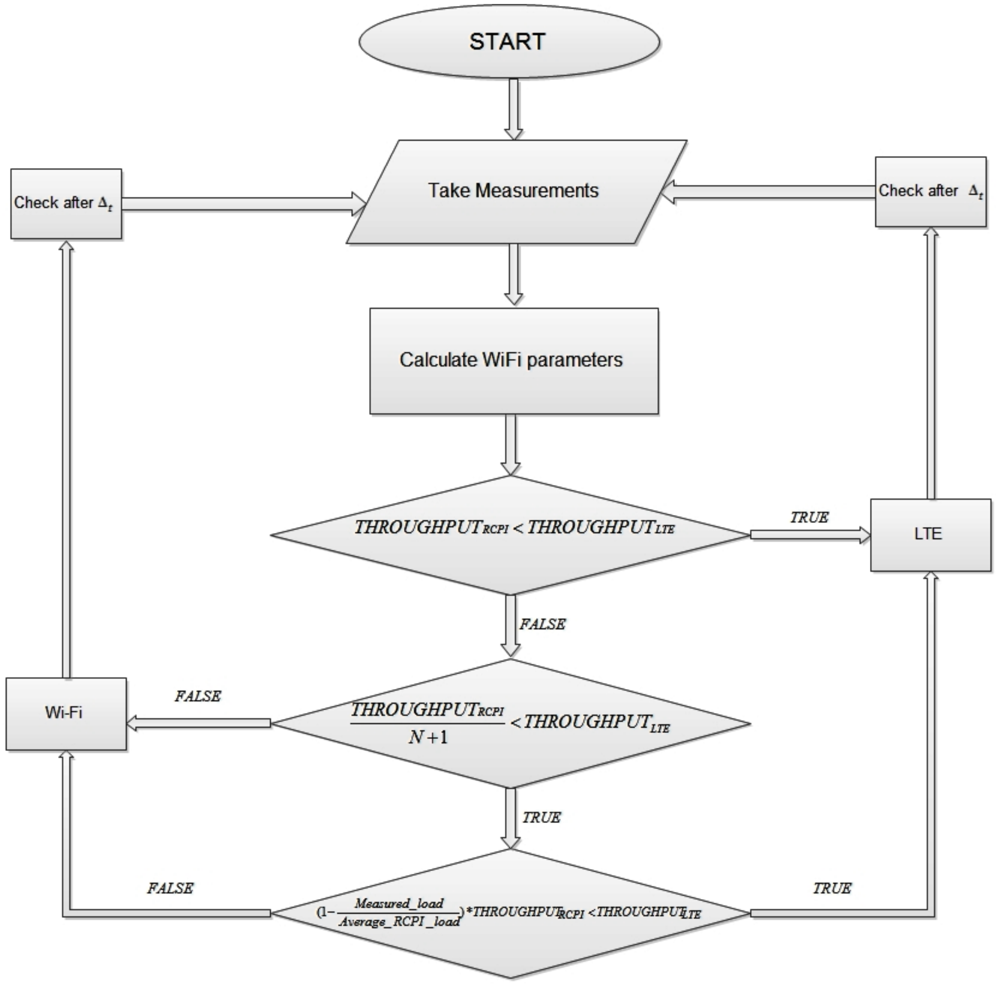

Figure 7: Flow Chart of Offloading Algorithm

Let Throughput_RCPI be the expected throughput for a given RCPI only when a single station is present in the network and Throughput_LTE be the expected throughput of a given LTE network.

Analysis for different cases :

- Heavily loaded and less number of stations:
  - If there are N number of dominant stations (N is defined earlier), in the worst case each station will share the time equally.
  - Therefore each station can expect an average time of 1/(N+1) for each second.

  - Since N is less (as per our assumption in this case) condition 2 will pass, provided Throughput_RCPI/(N+1) > Throughput_LTE.
  - Therefore Wifi is preferred.

- Heavily loaded and more number of stations:

  - When the network has high number of stations associated with it the time share is going to be less for a new station if it is going to associate with it. So condition two fails.
  - Since the load is also heavy the time share percentage based on load is also going to be less. So condition 3 fails.
  - Therefore LTE is preferred over Wifi in this case.

- Lightly loaded case:

  - Irrespective of the number of dominant stations associated with a given network, condition 3 passes provided Throughput_RCPI > Throughput_LTE.
  - Therefore Wifi is preferred in this case.

Precision of the above algorithm:

- We measured the load predicted for a lightly loaded case (for both higher and lower number of stations) and we cross checked this by finding the maximum bandwidth using a tool called "iperf" which shows the available bandwidth.

- This was done by running a server (connected through WiFi) and a client (connected through LAN).

- We then generated load in the network and again cross-checked the results.

- The algorithm was found to predict approximately equal results to those shown by iperf in both the cases.

7 Client Side

The software running in client side calculates various Wifi parameters periodically and creates an UDP socket and sends these data over the socket

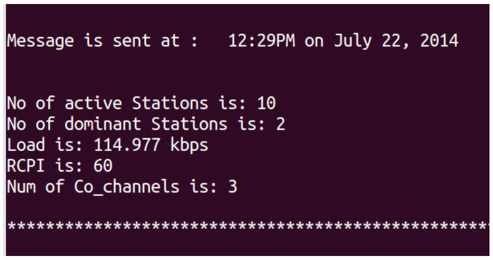

Figure 8: Client Side Message

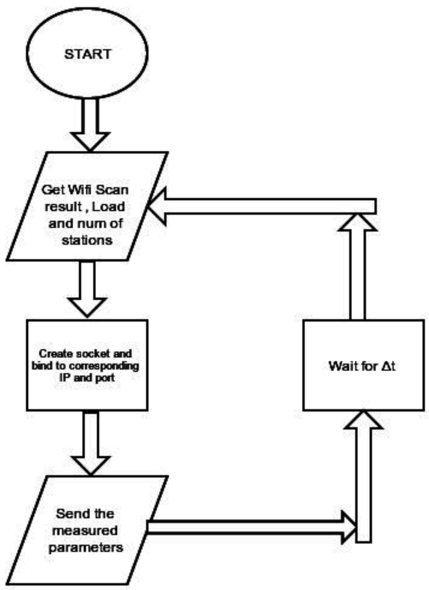

Figure 9: Flow chart Client side

8 Server Side

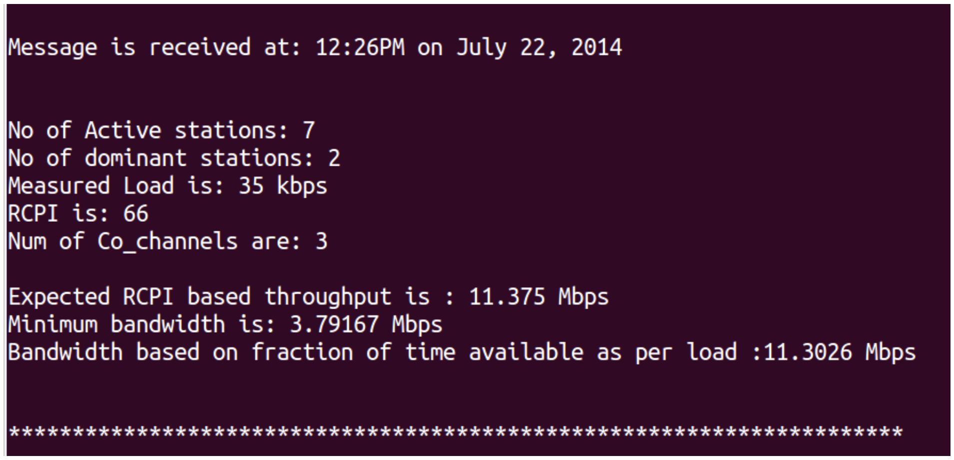

Figure 10: Server Side Message

The server side software receives the data from client and then retrives the parameters from it. Now it runs the offloading algorithm and checks if Wifi is better than LTE. Then it choses a mode. Now it creates an UDP socket and sends the video packets over this socket to the client who is listening in that particular port.

It periodically checks for data from client if it receives data it updates the mode (LTE or Wifi), else it continues to send data over the current mode.

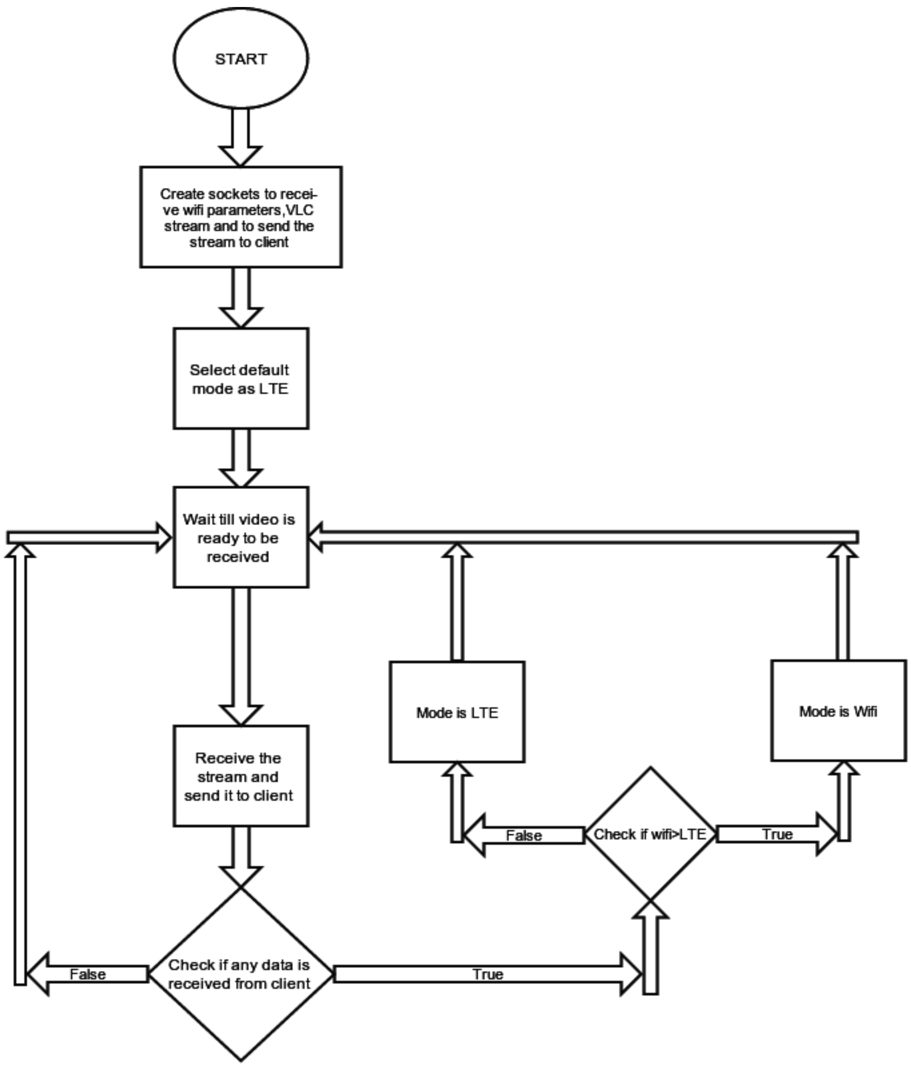

Figure 11: Flow chart Server side

9 Conclusion

The necessity of LTE Wifi offloading was analyzed and it has huge benefits. An offloading algorithm based on Wifi parameters was framed after conducting various tests and measurements. Wifi connection was made available for the client as an alternative. Now based on the offloading algorithm eNb decides which network to use to stream video. The softwares running on the client and server side ensure that data is successfully is routed through LTE or Wifi based on the decision made by eNb. The video was finally video by the client.

Performance of this algorithm for varying load and number of stations was tested and it was found to work well.

10 Future works

A better algorithm taking the following into account could be implemented:

- Fraction of time utilised by each station operating in the same channel
- Carrier sensing mechanism occuring due to multiple APs operating in same channel
- Interference effects due to signal from other APs and other devices operating in same bandwidth
- LTE parameters to predict LTE bandwidth

References

[1] Cisco. Secure wi-fi offload for untrusted networks: Cisco epdg evolved packet data gateway.

[2] https://www.cs.rutgers.edu/ pxk/417/notes/sockets. Introduction to sockets programming.

[3] IEEE. Telecommunications and information exchange between systems specific requirements. 2012.

[4] Tutorials Point. http://www.tutorialspoint.com/wi-fi/.

[5] Hughes Systique. Lte wifi data offload.