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Savitzky-Golay Filter Based Vertical Handoff between LTE and WIFI Network

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Abstract

Heterogeneous network is a network connecting computers and other devices with different operating systems. Wireless networking is becoming an increasingly important and popular way of providing global information access to users. In a fourth generation communication system, consisting of diverse variety of wireless access standards, network availability, coverage and quality of services may rapidly change depending upon the device mobility and fading suffered by the signal. The main challenges for seamless mobility is the availability of simple and robust vertical handoff algorithms, which allow a mobile node to roam among heterogeneous wireless networks. This paper provides enhanced location awareness of the mobile node and reduction in the adverse effect of fading, so that it is able to predict future network conditions accurately. This paper uses a filtering method named 'Savitzky-Golay' smoothening to reduce the effect of fading in the received signal, thereby reducing the unwanted handovers considerably. This paper also considers LTE and Wi-Fi for the ease of study due to their high bandwidth availability and ease of networking.

Keywords: LTE, Wi-Fi, Mobility, Savitzky-Golay Filtering, Signal Fading.

Introduction

Handoff is the process of changing the channel associated with the current connection while a call is in progress [1] .It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel. Poorly designed handoff schemes tend to generate very heavy signaling traffic and, thereby, a dramatic decrease in the quality of service (QoS). In order to establish an accurate handoff prediction system it is crucial for the mobile node to know the effect of fading over the received signal from the network and for the network to know the velocity-mobility pattern of the user. The extent of fading gives the mobile node (MN) a measure of loss of information and the mobility information gives the network to prioritize the handoff algorithm.

The velocity information of the mobile node plays a significant role in handoff decision algorithms. The challenge is to precisely predict the velocity of the mobile node and to calculate the accurate direction of motion of mobile node (MN).The velocity of MN can be resolved into 2 components: Radial velocity and Tangential velocity. The tangential component has negligible effect on signal strength[2] and handoff trigger but there dial component has considerable effect on the performance of the handoff prediction mechanism[2]. For the simplicity reason only the radial component of the MN velocity is considered in this paper.

In hand off decision, the location of MN also plays a vital role. The balance between the location and the velocity of MN is the most important challenge in the hand off management in 4G heterogeneous networks. The most important use of the location of MN is to predict the hysteresis threshold for the enhancement of the handoff decision[2]. The location of MN can be obtained from the GPS[3]. So the combination of Relative Signal Strength and mobility pattern of the MN would reduce the unnecessary handoff(Ping Pong)[4]. Another major factor influencing the handoff is the signal strength of the network or the base Station (BS) .Handoff to the next BS must be initiated when the received signal strength falls below a threshold value which is fixed with the help of location and velocity information of the MN.This ping-pong handoffs cause unnecessary signaling load and increases the traffic of the network. In order to avoid the ping pong handoffs it is vital to reduce the effect of fading in the signal received by the MN.

The fading effect can be broadly classified into two: **Fast fading** and **slow fading** [1]. The below proposed algorithm considers fast as well as slow fading. Slow fading is calculated using the empirical

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path loss model [5]. In this paper, Rayleigh fading distribution is used to calculate the fast fading because of the forward scattering property. The proposed algorithm, in particular, uses the Dent's Model for Rayleigh distribution since it is the most accurate and fastest algorithm.

Slow fading calculation:

P_k=32.44+20log$_{10}$R$_{km}$+20log$_{10}$f$_{MHz}$+L$_{gas}$+L$_{rain}$+L$_{pol}$+L$_{imp}$ +L$_{coup}$-G$_{tdB}$-G$_{RdB}$ ….(1)

P**$_k$* is the propagation loss suffered by the signal [4], ***R is the distance of the MN in Km and ***f*** is the frequency of the network (**2.5 GHz** for the Wi-Fi network and **2.0 GHz** for the LTE network)and ***L**$_{gas}$**, **L**$_{rain}$**, **L**$_{pol}$**, **L**$_{imp}$**, **L**$_{coup}$**, **G**$_T$ **dB**, **G**$_R$ **dB*** are the losses due to the environment variables such as polarization, coupling, antenna losses of transmitter and receiver, noise levels etc., The slow fading is given by the relation:
Slow fading=P$_k$+ shadow fading
Here shadow fading is assumed to be zero

Fast fading Calculation

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed. Calling this random variable *R*, it will have a probability density function.

$$P_r(r) = 2r/\Omega \exp(-r^2/\Omega), \quad r \geq 0 \quad \text{….(2)}$$

Implementation Of Savitzky-Golay Filter Based Vertical Handoff Algorithm(S-GVH)

A novel mathematical model was developed to computehandoff performance measures of interest. The procedure is very efficient for small as well as highRelative SignalStrength (RSS) threshold levels, but the computational complexity grows polynomial in the averaging parameter of the so used Savitzky-Golay filter. The discrete-time approach in [7] can be extended to the case of soft handoff [6].

The block diagram of the proposed algorithm is shown in fig 1. It comprises of velocity calculation unit and location calculation unit from GPS, RSS measurement unit considering the fast fading and slow fading, a handoff trigger unit and handoff execution unit.

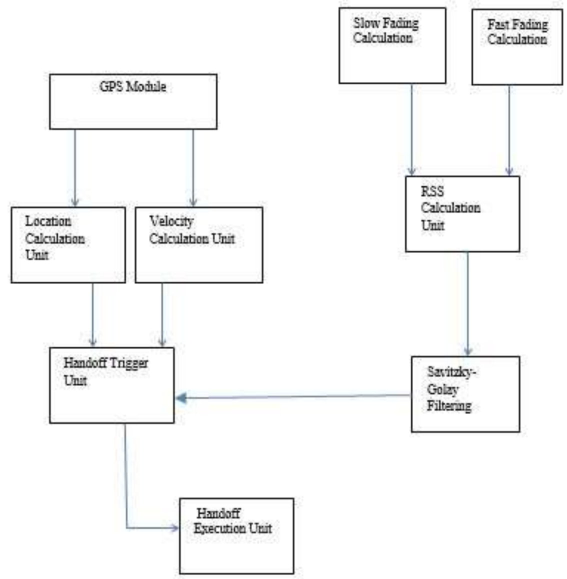

Fig: 1 Block Diagram S-GVH Algorithm

Velocity and location:

Location is calculated using from the GPS device of the MN and velocity is calculated. After getting co-ordinates of the MN the velocity is calculated using distance formula as given in equation 3.

$$R = \sqrt{(x_2 - x_1)^2 - (y_2 - y_1)^2} \text{.............. (3)}$$

Where (x_1, y_1) and (x_2, y_2) are the previous and present co-ordinates of the MN and time at each coordinate.

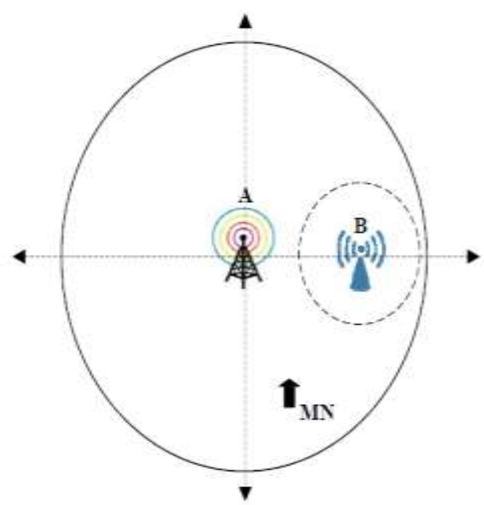

Fig.2 Diagrammatic Representation of Simulation Model

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In Fig.2 *'A'* represents the Base Station of LTE and *'B'* represents the Access point of Wi-Fi. The outer circle represents the service range of the LTE network and dotter inner circle represents the service range of Wi-Fi network. The *'MN'* represents the Mobile Node which is in random motion.

Savitzky- Golay Filtering

This algorithm is a smoothing filter that essentially applies a polynomial regression of a certain degree to a time-series. The advantage of the Savitzky-Golay smoothening filter is that it tends to preserve certain features of the time-series like local minima and maxima [9]. The smoothing is computed using the algorithm described by Savitzky and Golay. The algorithm computes a local polynomial regression on the input data by solving the equation:

$$Y= a0+a_1z^1+a_2z^2+a_3z^3+\ldots\ldots.+a_kz^k$$

Savitzky and Golay proposed a method of data smoothing based on least – square polynomial approximation.

The MATLAB Signal Processing Toolbox has a function **sgolayfilt (x,k,f)[**12] where x is the signal, k is the degree of the polynomial used for least square approximation and f is the number of point average taken (for example: 5point average) (generally referred to as span length).For designing and implementing both symmetric and non symmetric S-G filters. There are some important constraints in the use of polynomial fitting in general:

•The span must **(f)** be odd.

•The polynomial degree **(k)** must be less than the span.

•The data points are not required to have uniform spacing.

Results & Discussions

a) Handoff procedure for single mobile node

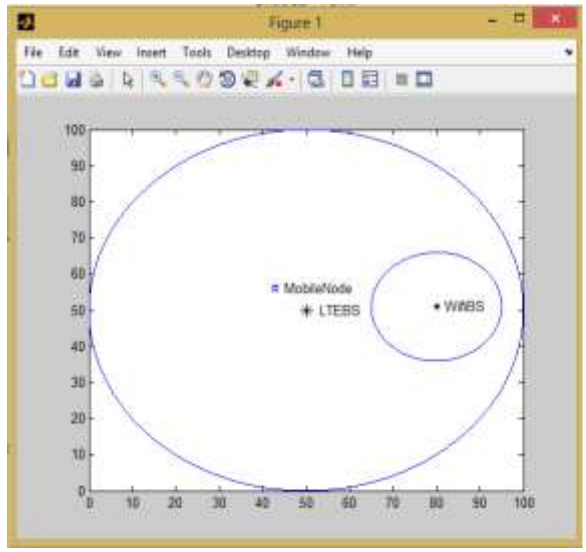

Fig 3. Handoff procedure with single mobile node

b) Handoff procedure for multiple mobile nodes

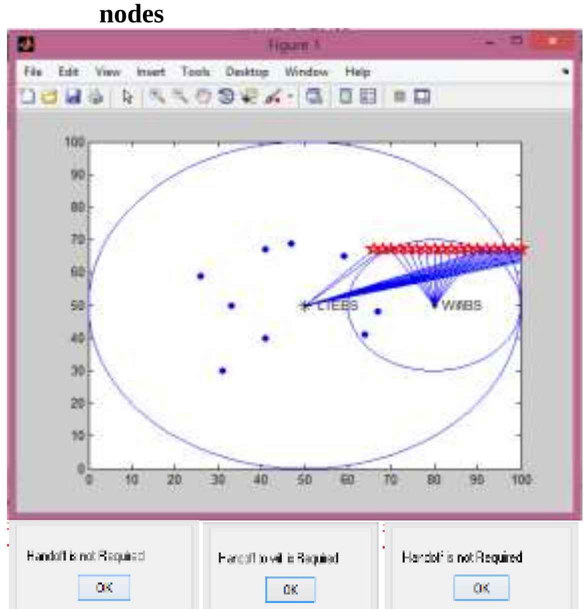

Fig 4 : Handoff procedure with single mobile node

c) RSSI at each point

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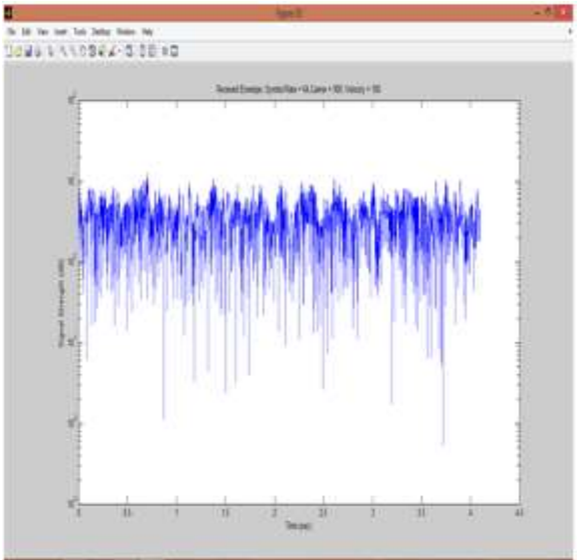

Fig 5 : Received signal strength at each point

d) RSSI of Idle Channel

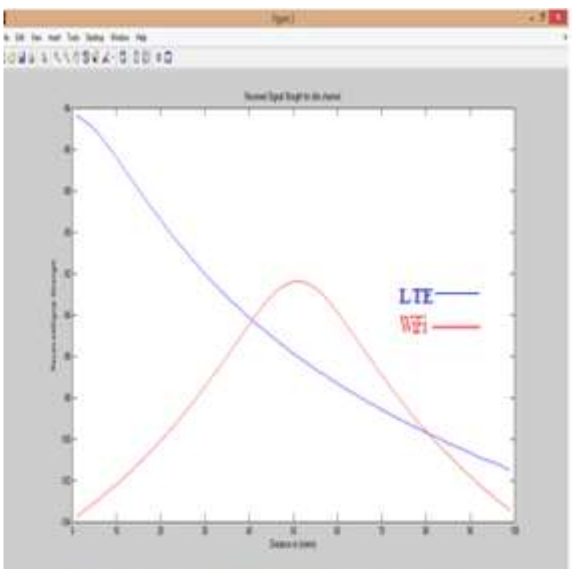

Fig 6: Received signal strength of idle channel.

e) Handoff procedure without S-G Filtering

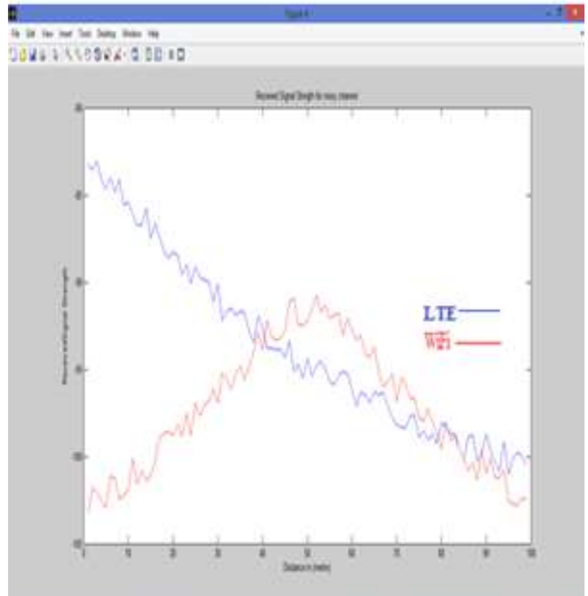

Fig 7 Handoff procedure without S-G Filtering

Fig.7 shows the Relative signal strength (dBm) of the LTE and Wi-Fi networks and the network state (lower level denotes the LTE and the higher level denotes the Wi-Fi network state of the MN). Here the RSS calculated have all the adverse effects of the multipath fading and it leads to the false handoffs

f). Handoff prediction with S-G Filtering

Fig.8 shows the Relative signal strength (dBm) of the LTE and Wi-Fi networks the network state (lower level denotes the LTE and the higher level denotes the Wi-Fi network state of the MN). It is easily interpreted from the graph that the RSS of LTE and Wi-Fi is completely devoid of the fading effect and noise. It is performed by using the Savitzky-Golay filter while preserving the constraints of the signals. The handoff prediction occurs without any error and unnecessary handoffs are avoided.

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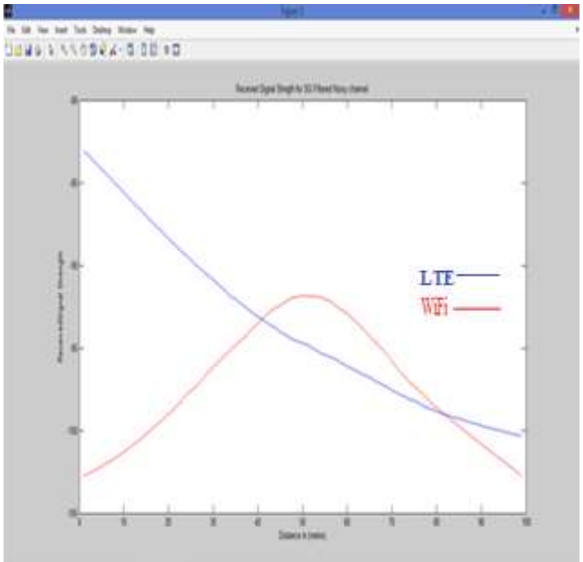

Fig 8 Handoff prediction with S-G Filtering

Conclusion

It can be concluded that the proposed S-GVH (Savitzky- Golay Filter Based Vertical Handoff) algorithm outperformed the other method using relative signal strength. This algorithm is also superior to the handoff algorithm based on distance and hysteresis. Moreover, it should be noted that the performance of the proposed S-GVH Algorithm is not dependent too much on which RSS threshold level being set, because it utilizes both trajectory information of MN in handoff decision making. Using S-GVH Algorithm the fluctuations in signal can be smoothened thereby preventing the MN from making unnecessary or false handoffs and thus the quality of service can be increased.

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