Handoff Scheme for Terrestrial Mobile and Satellite Convergence Networks with Incorporation of Pattern Recognition Algorithm

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ABSTRACT

As the communication becomes a global affair today, engineers had begin to look into the heterogeneous network solution for faster and cheaper deployment. For heterogeneous network to function properly, efficient and effective mobility management is vital to ensure uninterruptable and ubiquitous connection. Recently there has been many works done to replace the traditional handoff decision algorithm such as hysteresis and fuzzy logic based handoff algorithm, especially in the heterogeneous environment. The fuzzy handoff algorithm proposed by earlier work is not optimized and required constant attention from the human experts. This paper proposes a newer approach using Adaptive Network Fuzzy Inference System (ANFIS) where the training element is incorporated into the existing fuzzy handoff algorithm. This paper also discusses the effective mobility management strategy to suit the hybrid terrestrial and satellite segment.

Keywords

Heterogeneous Network, ANFIS, Fuzzy Handoff, Mobility Management

1.0 INTRODUCTION

Whilst today's terrestrial communication system has been very well established, there is still a great deal of territory that has no satisfactory coverage. To fulfill the aspiration of a truly global coverage communication, the connectivity of anyplace, anytime and anyone has to be satisfied. However, the problem lies on the existing backbone where it cannot be extended into the area where the communication tower cannot be economically built. The obstacles in terms of terrain and vegetation have posed a great challenge for engineers to fulfill the global communication aspiration. The use of satellite technology to complement the existing terrestrial networks is seen to be an excellent choice to narrow the gap of the "dark" spot of the wireless network coverage. Taking advantage of its global nature, satellites can cover a large area, even into the places where the terrestrial coverage is almost considered impossible.

The idea of converging satellite and terrestrial hybrid network is not new and many notable research projects especially in Europe have been investigating its practicality and usability. For instance the ACT Satellite Integration into Networks for UMTS Services (SINUS) project looked into the possibility of integrating Space-segment UMTS (S-UMTS). (Priscoli, 1999) The Multi-segment System for Broadband Ubiquitous Access to Internet Services and Demonstrator (SUITED) project funded by the European Union under the IST Program had looked into the performance of hybrid networks especially in the heterogeneous environment (P. Conforto et. al., 2002).

For a hybrid networks to function without any significant interruption, several issues on mobility management needs to be addressed. The different requirements and expectation of space and terrestrial segment for instance has made the handoff decision task to be more challenging while the existing handoff decision algorithm is not suitable in the heterogeneous networks.

In this paper we propose some mobility management strategies to support efficient handoff in the heterogeneous networks. We also propose a rather new handoff decision algorithm incorporating optimsation method such as fuzzy logic and hybrid algorithm, i.e. the Adaptive Neuro Fuzzy Inference System (ANFIS).

2.0 MOBILITY MANAGEMENT STRATEGY

2.1 Connection Transference Scheme

Traditionally, handoff connection transference scheme rely heavily on hard handoff, and usually a preferred scheme due to its simplistic nature. In hard handoff scheme, the connection is usually severed first before establishing into a new base station. This however is not suitable for hybrid satellite and mobile scenario due to the longer propagation delay.

Another type of connection transference scheme is the soft handoff scheme, where the transference of the network bearer from old base station to the new base station is done gradually. In the soft handoff scheme for Universal Mobile Telecommunication System (UMTS), both traffics from old and new base station will be combined at the Radio Network Controller (RNC). However due to the big difference in the propagation delay between satellite and terrestrial, this scheme will experiencing problems of synchronization when combining both new and old base station.

The most suitable scheme for hybrid satellite and terrestrial network is the signaling diversity. This scheme will initiate the signaling messages when it detects the degradation in the link quality. Once the signaling has completed the traffic will be rerouted immediately to the new base station (F. Daoud, 2000).

2.2 Connection Establishment Scheme

In general there are two types of connection establishment scheme, backward and forward handoff scheme. In the backward handoff scheme, the signaling messages exchange is done via the old base station until a firm connection has been established, before connection is severed and transfer to the new base station.

The forward handoff on the other hand, exchanging signaling messages through the new base station while the traffic is still flowing through the old base station. This is to increase the reliability especially in the satellite scenario where the sudden change in the radio environment will happen and hence the link disruption before the completion of the signaling messages.

The forward handoff scheme is thus usually a preferred choice when the system involving the space segments (F. Daoud, 2000).

2.3 Connection Controlling Scheme

The connection controlling scheme on the other hand consists of four categories, i.e. The Mobile Controlled Handoff (MCHO), Network Controlled Handoff (NCHO), Mobile Assisted Handoff (MAHO) and Network Assisted Handoff (NAHO). MAHO and NAHO is more reliable as both performance measurement from mobile and base station are taken into consideration. This however is not suitable for mobile and satellite networks as the load of signaling exchange messages are high. This will use up the already limited bandwidth of the satellite link. Table 1 summarizes the comparisons of the connection controlling scheme. MCHO is seen to be a more suitable candidate for the hybrid mobile and satellite connection controlling scheme. (Min Liu, 2008 & F. Daoud, 2000).

Table 1: *Comparisons of different connection controlling scheme.*

Characteristics	**MCHO**	**NCHO**	**MAHO**	**NAHO**
HO Process	C	C	D	D
Terminal Complexity	High	Low	Moderate	High
Speed of HO	Fast	Slow	Slow	Fast
Signalling Load	Low	Low	High	High
Reliablility	Moderate	Moderate	High	High

C – Centralised
D – Decentralised

3.0 HANDOFF DECISION ALGORITHM

3.1 Traditional Handoff Algorithm

The traditional handoff decision algorithm relies on the single metric measurement. For instance, most cellular communication technologies are using Received Signal Strength Intensity (RSSI) as the reference to decide initiation to handoff. When the RSSI attenuates to a certain threshold, usually at approximately 100dBm, a handoff will be initiated. The traditional handoff algorithm is a preferred choice for a simpler terminal due to its simplistic nature. However in the mobile broadband environment, the handoff decision needs to take more inputs to avoid unnecessary handoff (J. M. Holtzman and A. Sampath 2001).

3.2 Fuzzy Handoff Algorithm

The use of fuzzy logic (L. A. Zadeh 1965) in the handoff decision making algorithm as many researchers had previously investigated its validity, practicality and performance. Fuzzy logic has been applied successfully in many applications especially in control systems and data acquisition. With its ability of dealing with imprecise data, fuzzy logic seemed to be an ideal choice in the environment of uncertainty, especially in the unpredictable radio environment (Q. Razouqi, H. J. Schumacher and A. Celmins S. Ghosh 1998).

Figure 1 shows the block diagram of fuzzy logic based handoff algorithm. In the application of fuzzy logic in handoff algorithm, the crispy data is first change into non-crispy manner through the process of fuzzification. For instance, in Fig.1, the crispy data, RSSI, BER and QoS is converted into non-crispy in the fuzzification process. In the fuzzification process, the crispy data is mapped into the equivalence of its non-crispy using pre-defined membership functions, such as given in Fig. 2.

Then the data is analysed in the fuzzy inference engine using If-Then rules and the analysed data is being converted back into crispy manner through the process of defuzzification. The data after the defuzzification process is known as the handoff factor, or handoff sensitivity. The decision for handoff can be determined by setting a threshold line, where if the value of handoff factor is above the threshold, then handoff initiation protocol will be triggered.

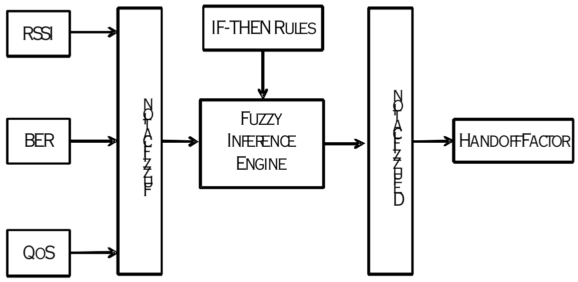

Figure 1: Fuzzy Handoff Algorithm Block Diagram

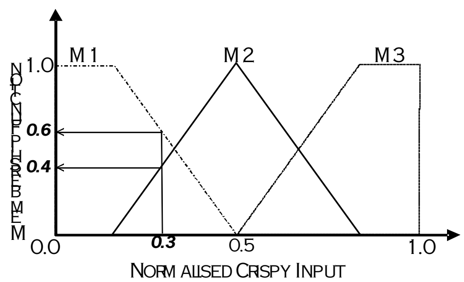

Figure 2: Example of a Membership Function

3.3 ANFIS Handoff Algorithm

While fuzzy logic seemed revolutionary when solving problems of uncertainty in the collected data, it has flaw of its own. The original fuzzy system needs to define by experts through experience and carefully designed questionnaires. To mitigate this problem, a learning algorithm is added into the existing fuzzy logic algorithm. The most suitable hybrid algorithm we found out is the Adaptive Neuro-Fuzzy Inference Engine (ANFIS). ANFIS (J-S. R. Jang, 1993) was proposed by R. Jang in 1993 incorporating the best of fuzzy logic and the training element provided by the artificial neural network.

Figure 3 showed the proposed ANFIS based handoff algorithm. In the ANFIS algorithm, the system is divided into five layers. In the first layer, the membership function are defined usually using a clustering method and a premise parameters is defined. In the second layer, the each f the node define the firing strength of the fuzzy rules while in the third layer normalized the firing strength. Finally the fourth layer adapts with an output node and the fifth layer sums all incoming signals from previous four layers.

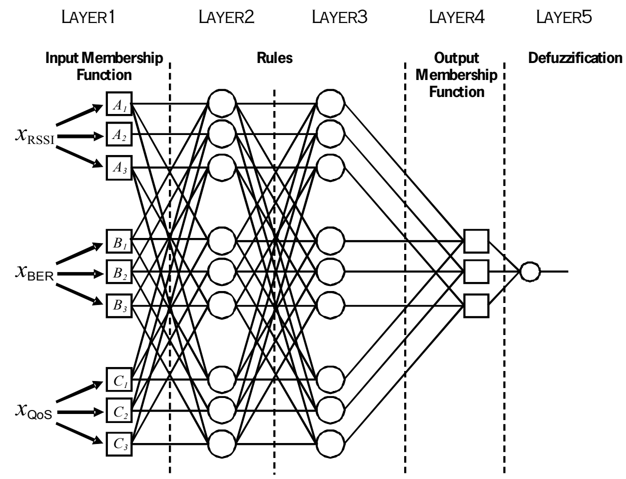

Figure 3: Proposed ANFIS Based Handoff Algorithm

4.0 SIMULATION

4.1 Methodology and Simulation Setup

In the simulation conducted using OPNET Modeller to test the algorithm for fuzzy handoff while the ANFIS handoff algorithm is tested using MATLAB to compare its effectiveness as compared with the fuzzy handoff algorithm.

A scenario has been created where two segment, satellite for the space segment and Wireless Local Area Network for the terrestrial segment, work together as a hybrid system. The satellite radio environment is assumed to be under the influence of shadowing, where Lutz's model (E. Lutz, 2000) is used to model the shadowing. Lutz's model is a statistical model which is more popularly used due to its simplicity nature. This model, as shown in Figure 4 is an event oriented model, using 2-state Markov model where one state is denoted as "good" channel which is Rician distributed, while another state is denoted as "bad" state, which is Rayleigh / Lognormal distributed. The mean duration in "bad" state is given as D_b while the mean duration in "good" state is given as D_g . The time-share of shadowing, A i.e the time when the channel is at the "bad" state can be represented as in (1). Figure 5 shows the simulated Lutz's model in MATLAB (R.A. Wyatt-Millington, R.E. Sheriff, Y.F. Hu 2007).

$$A = \frac{D_b}{D_g + D_b} \qquad (1)$$

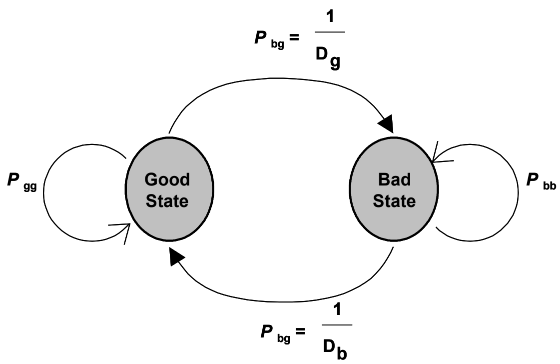

Figure 4: Lutz's 2-state Markov Model

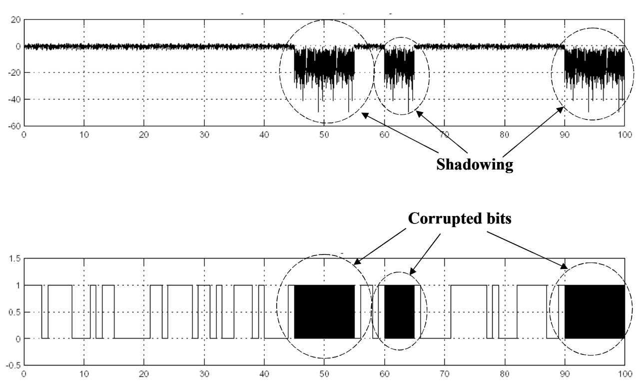

Figure 5: *Simulated shadowing event based on Lutz's Model*

The terrestrial segment radio impairment on the other hand is simulated using the standard path loss model, given as in (2), below: -

$$PL = \left(\frac{G_t G_r \lambda}{4\pi R} \right)^2 \qquad (2)$$

Where

R = Path length in meter
λ = Wavelength in meter
G_t = Antenna gain of the transmitter
G_r = Antenna gain of the receiver

The antenna gain is assumed to be unity. The model for the signal variation caused by the mulitpath problem is the Rayleigh fading model, is given its probability density function, $p(r)$ as below: -

$$p(r) = \frac{r}{a^3} \exp\left(-\frac{r^2}{a\sigma^2} \right) \quad (0 \le r \le \infty) \qquad (3)$$

Where σ is the variance of the standard deviation of the signal variations.
The BER is modeled assuming the Binary Phase Shift Keying is used under the influence of the Additive White Gaussian Noise (AWGN). The BER is thus generated using the complementary error function as shown in (4)

$$p_b = \frac{1}{2} \operatorname{erfc}\left(\sqrt{\frac{E_b}{N_0}} \right) \qquad (4)$$

where $\frac{E_b}{N_0}$ is the energy per bit to noise ratio.

4.2 Results

The results obtained are as presented in Figure 6 and 7. Figure 6 shows the fuzzy handoff algorithm reacts in the event of shadowing. This shows the algorithm is applicable in this scenario. However when we refer to the comparison between the fuzzy logic based handoff and ANFIS, as shown in the cumulative distribution analysis in Figure 7, ANFIS has a lower handoff rate than fuzzy logic based handoff while still maintaining practical communication link. This is due to the training done on the fuzzy rules and membership function to suit to the changing of radio environment. The lower handoff rate will reduce the requirements for signaling load and lower the possibility of link break due to the handoff failure.

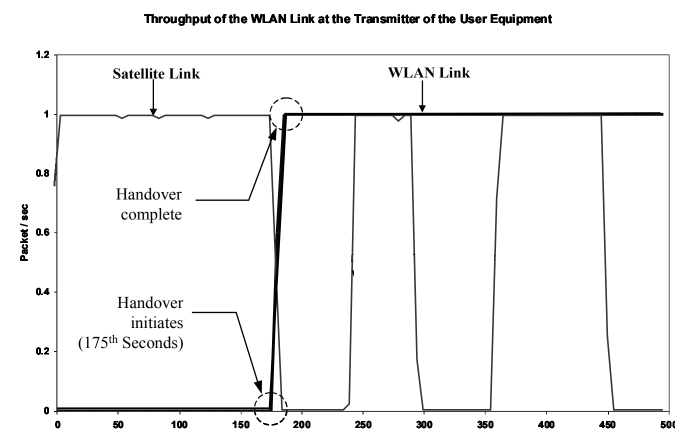

Figure 6: Throughtput of the WLAN link and satellite link at the receiver of both WLAN and satellite MT when applying fuzzy handoff algorithm

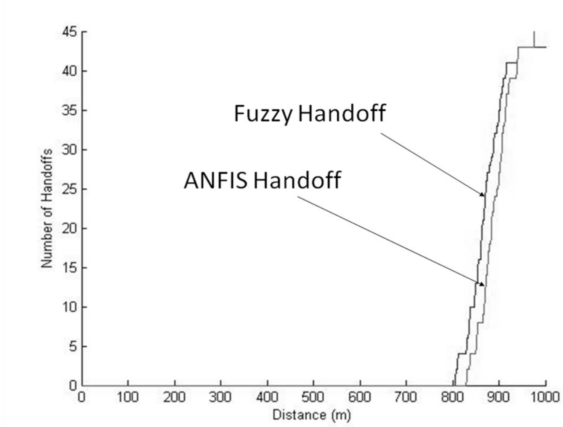

Figure 7: Cumulative Distribution for both Fuzzy and ANFIS Handoff Algorithm

5.0 CONCLUSION

This paper has presented two issues involving effective mobility management for satellite and terrestrial convergence networks. The strategy was designed based on the necessity and the scenario involved. For instance MCHO is considered most suitable for this application as it involved the least signaling load and has at least a moderate reliability.

On the other hand, this paper also discuss the methodology of using fuzzy logic to make handoff decision while ANFIS were proposed to improve the performance of the fuzzy handoff algorithm, as illustrated in Figure 7. At the time of writing, more analysis is currently being formulated to explore more effective way for handoff decision to ensure better decision is made for handoff.

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