Vertical handoff model in next generation wireless networks

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Abstract. The purpose of this research is to propose a scheme for making handoff decisions effectively. We propose a handoff decision strategy through a fuzzy logic system to perform a seamless handoff. We combine four types of determinants, namely, RSS (received signal strength), data rate, network latency, and user preferences as input metrics to our fuzzy inference engine. RSS is pre-processed first by the Kalman filter to get rid of noise. The logic of the inference engine is realized on the User Equipment side as a faster reaction to network dynamics. Our scheme performance is evaluated by simulating mobility scenarios through the context of move-out and move-in scenarios. Simulation results show that our scheme outperforms other approaches in terms of reducing unnecessary handoff for all cases.

1. Introduction

Next generation wireless networks (NGWN) enable mobile users to explore heterogeneous networks using UE (user equipment) devices with multi-interface facilities when accessing real time and non-real time services. Multi-radio operation in a heterogeneous environment is now normal. 4th generation (broadband) mobile broadband technology has implemented multi-network integration such as WLAN and mobile telecommunication networks through the all-Internet protocol base for broadband mobile capacity [1,2].

Handoff decision is the process of choosing the best network access in a situation and deciding when to handoff or not at the right time. Traditional handoff or horizontal handoff involves the process between two adjacent cells on the same radio access technology. Certain link quality parameters such as RSS (received signal strength) or signal-to-noise ratio are commonly considered in handoff management. When the parameter in question is below a predetermined threshold, a handoff will be initiated. Due to differences in protocol structure and parameters involved in heterogeneous environments, horizontal handoff mechanisms do not serve well in the environment [3,4]. On the other hand, handoffs between different radio access technologies often occur when mobile users explore them. Specifically, handoffs that involve exchanges between different types of network access are called vertical handoffs [5].

As far as the handoff decision is concerned, traditional algorithms that use RSS as the main factor can cause not only ping-pong effects but also network load imbalances [6]. RSS is indeed practical but appears to be of limited use in the context of heterogeneous networks because RSS measured by different radio interfaces in general cannot be compared. However, RSS is still the most common metric that can be accepted by the device so we still consider RSS as a determining factor in triggering the handoff.
process. Also, in the case of tradeoffs among other metrics needed to make vertical handoff decisions, we consider other factors namely data rate and network latency as multi-criteria input in a fuzzy logic system to produce a single output value, which indicates whether vertical handoff is important immediately [7].

Our scheme focuses on communication simulations where IEEE 802.11 wireless networks are on cellular networks [8]. RSS provides information about the level of power received by the antenna. The power is reduced when the user moves away from the IEEE 802.11 access point (AP). Mobile users should switch to the cellular network before losing connection. Data rate is used to indicate the condition of network bandwidth; network latency is one of the QoS parameters that represent a round trip time delay that occurs in data communication on a network. Thus through this proposed design, we develop a scheme to determine when to carry out a moderate handoff decision.

2. Methods

Simulation methods are applied to find research solutions in our designs. This method directs us a road map to synthesize previous research work related to the design of research simulations and extend work to more specific areas such as identifying research questions, choosing a simulation approach, developing computational representations, elaborating basic rules of verification vs. experimentation, and evaluating research simulations [9].

Through this approach, we are motivated to look for visualization of small-scale or simple systems where the effect of certain controls on parameters is really expected to resemble the actual state or system. In this research, we use the Mamdani version of fuzzy logic as an inference engine to deduce handoff decisions [5]. Likewise, we evaluate and compare simulation results to verify the designed system performance. Four input metrics namely RSS, data rate, user preference and network latency are randomly combined research subjects. The fuzzy logic method and the filtering process are adapted to reasoning the output of the handoff decision making system (Figure 1).

![Figure 1. Block diagram of a fuzzy logic system.](image-url)

The rule base contains IF-THEN rules that are required by the Fuzzy Inference System (FIS). We apply FIS Mamdani because it is intuitive, widely accepted and operates according to human instincts. The database defines the membership function of the fuzzy set. FIS generates fuzzified aggregate data, based on the fuzzy inference method. Defuzzifier converts fuzzified aggregate data into scalar values. The set of fuzzy output decisions is aggregated into a single fuzzy set and passed to the defuzzifier to be converted to the right quantity, the handoff factor, which determines whether a handoff is needed. We designed four fuzzy input variables and three fuzzy sets for each fuzzy variable, so that the maximum number of rules in our rule base is $3^4 = 81$. The sharp output from the defuzzifier block is used to select the network that is most suitable for the UE. The universe of discourse for handoff factor variables ranges from 0 to 10 as shown in Figure 2.
Figure 2. Membership function of the handoff factor.

The handoff process is diagramed in Figure 3. First, a UE constantly monitors RSSs of a serving point of attachment to the system, either an AP or a base station. Then, the Kalman filter will offset the effect of noise interference in which its Kalman-filtered RSSs will be merged with other three parameters to be processed by the FIS. After determining the move-out or move-in scenario, the output of the FIS will indicate whether the UE should initiate a vertical handoff or stay connected with the current network.

When the UE is departing from an AP, this is referred to as a move-out scenario, where the UE is expected to perform a vertical handoff to the cellular network soon. On the contrary, if the UE is associating to an AP from the cellular network, a move-in scenario happens, during which another vertical handoff shall occur shortly. Considering different mobility behaviours, handoff decision is made in the following lines:

- For the move-out scenario, if the deduced handoff factor is less than or equal to 3, then the UE selects the cellular network.
- For the move-in scenario, if the handoff factor is greater than or equal to 5, then the UE selects WLAN.
- If the handoff factor is between 3 and 5, then the UE stays connected with its current access network.

Figure 3. Workflow handoff process.

3. Results and discussion

Let us now investigate how the Kalman filter enacts the role of mitigating ping-pong effects. For simplicity, suppose that RSSs become a sole cause to trigger handoff, which is indicated with a control signal producing either 0 or 1. Accordingly, Figure 4 depicts handoff occurrences without and with using the Kalman filter in the move-out scenario. Each rising or falling edge of the signal represents a vertical handoff. From the figure it can be seen that, although RSS variations may cause frequent handoffs, such
phenomena are greatly improved with the Kalman filter. Figure 4 also suggests the usefulness of the Kalman filter that prevents handoff from happening more frequently than necessary. While the Kalman filter is effective in dealing with RSSs, there are other practical determinants affecting handoff decision.

![Figure 4](image)

Figure 4. Handoff control signal without and with the Kalman filter.

Next we concentrate on how many handoffs are initiated during simulations. In the move-out scenario, the UE performs 36, 35, 29, and 21 vertical handoffs with the traditional fixed-RSS, Kalman-filtered RSS, Mamdani fuzzy logic, and our design, respectively (Figure 5). From Figure 5, it can be seen that the last three approaches reduce handoffs considerably in comparison to the traditional one, with relative reductions reaching 2.78%, 19.4%, and 41.67%, respectively. Relative reductions are assessed below:

$$\frac{(36 - 35)}{36} \times 100 = 2.78\%$$
$$\frac{36 - 29}{36} \times 100 = 19.4\%$$
$$\frac{36 - 21}{36} \times 100 = 41.67\%$$

Concerning the move-in scenario, we have 33, 30, 30, and 18 handoffs resulting from the fixed-RSS, Kalman-filtered RSS, Mamdani fuzzy logic, and the proposed approach, respectively (Figure 6). With similar computation to that in Figure 6, we summarize that, when compared with the fixed-RSS approach, the last three schemes reduce handoffs by 9.09%, 9.09%, and 45.45%, respectively.

![Figure 5](image)

Figure 5. Handoff counts for different subject schemes in the move-out scenario.
4. Conclusion

Foregoing experiments show that the Kalman filter contributes to reducing signal fluctuations due to shadowing effects. Consequently, the Kalman-filtering RSS approach brings about fewer handoffs than the fixed-RSS scheme does. However, RSS as a single metric is not enough. Accordingly, the amalgamation of a Kalman filter and fuzzy system for vertical handoff decision making with multi input metrics is proposed in this study.

Combining a Kalman filter and a fuzzy system for smooth handoff in a heterogeneous networking environment, this paper devised a means to fuse four types of determinants for joint decision making. We developed a Mamdani fuzzy inference system that takes into account multi-attributes of different potency to resolve a moderate decision indicative of handoff initiation. Our approach was compared quantitatively with other schemes, showing the usefulness of our development in all scenarios.

References

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