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Handover in Wireless Mesh Network

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Abstract: Nowadays, Wireless Mesh Network is the best solution for extending the coverage of Wireless LAN. Users move to wireless communication networks and expect the same level of performance as their wire line counterparts. Therefore, much research effort has been devoted to investigating how to optimally address the challenges posed by wireless multimedia communications. In this paper, the authors present Wireless Mesh Network and describe the handover schemes, leading to a new method for optimizing handover and a new power control approach.

Key words: Wireless Mesh Network, handover, soft handover.

1. Introduction

1.1 Wireless Mesh Network

As various wireless networks evolve into the next generation to provide better services, a key technology, Wireless Mesh Networks (WMNs), has emerged recently. In Wireless Mesh Network, nodes are comprised of mesh routers and mesh clients [1]. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. A Wireless Mesh Network is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among them.

Wireless Mesh Network consists of three types of architecture based on the functionality of the nodes.

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Infrastructure / Backbone Wireless Mesh Network (Fig. 1) is the most commonly used type. This type of Wireless Mesh Network includes mesh routers forming an infrastructure for clients that connect to them.

Client Wireless Mesh Network (Fig. 2): Client meshing provides peer-to-peer networks among client devices. In this type of architecture, client nodes constitute the actual network to perform routing and configuration functionalities as well as providing end-user applications to customers.

Hybrid Wireless Mesh Network: This architecture is the combination of infrastructure and client meshing as shown in Fig. 3.

Wireless Mesh Network has many characteristics as below:

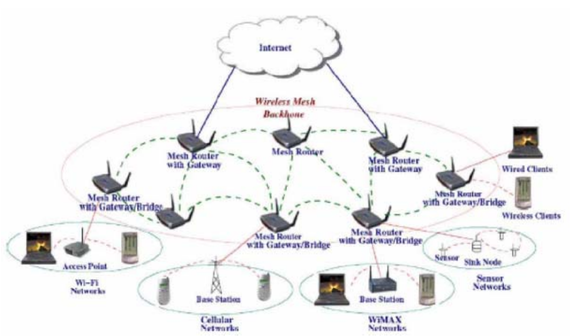

Fig. 1 Infrastructure/Backbone Wireless Mesh Network.

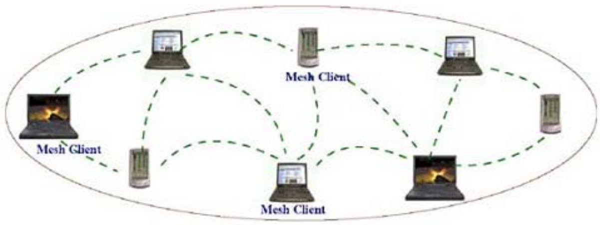

Fig. 2 Client Wireless Mesh Network.

Fig. 3 Hybrid Wireless Mesh Network.

- Multi-hop wireless network.
- Support for ad hoc networking, and capability of self-forming, self-healing, and self-organization.
- Mobility dependence on the type of mesh nodes.
- Multiple types of network access.
- Dependence of power-consumption constraints on the type of mesh nodes.
- Compatibility and interoperability with existing wireless networks.

1.2 Handover

One of the main characteristics of mesh networks is that they have only a few wireless gateways (WGs) connected to a wired network while the wireless routers (WR) provide Network access to mobile. Within the range of a given wireless router, the client may move freely, but as it moves away from the wireless router and closer to another, it should handover all its open connections to the new one to preserve network connectivity [2]. Ideally the handover should be completely transparent to mobile clients with no interruption, loss of connectivity, or degradation of voice quality if VoIP communications are involved. Handover is the essential component for dealing with the mobility of clients. It guarantees the continuity of the wireless services when the client moves across the boundaries.

1.2.1 Types of Handover in Wireless Mesh Network Systems

There are four different types of handovers in Wireless Mesh Network [3]. They are:

(1) Intra-system HO: occurs within one system. It can be further divided into Intra-frequency HO and Inter-frequency HO. Intra-frequency occurs between cells belonging to the same Wireless Mesh Network carrier, while Inter-frequency occurs between cells operate on different Wireless Mesh Network carriers.

(2) Inter-system HO: takes places between cells belonging to two different Radio Access Technologies (RAT) or different Radio Access Modes (RAM).

(3) Hard HO: is a category of HO procedures in which all the old radio links of a mobile are released before the new radio links are established. Hard handover can take place as intra or inter-frequency handover.

(4) Soft HO: During soft handover, a mobile simultaneously communicates with two (2-way SHO) or more cells belonging to different APs of the same wireless gateway (intra-WG) or different wireless gateway (inter-WG). Soft handover is only possible within one carrier frequency and therefore, it is intra-frequency handover processes.

1.2.2 Conditions of Handover

- Mobile node is working and moving from the coverage of this AP to the others.
- Mobile node is in the intersection of two coverage causes the increment of bit error rate => quality handover.
- The traffic is saturated need to handover some mobile node to the new AP => traffic handover.

1.2.3 Objectives of Handover

- Guaranteeing the continuity of wireless services.
- Keeping required QoS.
- Minimizing interference level of the whole system by keeping the mobile linked to the strongest AP.

- Roaming between different networks.
- Distributing load from hot spot areas (load balancing).

2. Soft Handover (SHO)

This paper will only focus on soft handover. Soft handover has quite a few inherent advantages. However, it also has the disadvantages of complexity and extra resource consumption.

2.1 Principles of Soft Handover [3]

Soft handover is different from the traditional hard handover process. With hard handover, a definite decision is made on whether to handover or not and the mobile only communicates with one AP at a time. With soft handover, a conditional decision is made on whether to handover or not. In the interim period of soft handover, the mobile communicates simultaneously with all the APs in the active set. Hard handover happens on a time point; while, soft handover lasts for a period of time.

Fig. 4 shows the basic process of hard and soft handover (2-way case). Assuming there is a Mobile node moving from AP_1 to AP_2, AP_1 is the mobile's original serving AP. While moving, the Mobile node continuously measures the pilot signal strength received from the nearby APs. With hard handover shown as (a) in Fig. 4, the trigger of the handover can be simply described as:

If (pilot_$E_c/I_0)_2$ - (pilot_$E_c/I_0)_1$ > D and AP_1 is the serving AP
Handover to AP_2 ;
else
do not handover ;
end

Where (pilot_ $E_c/I_0)_1$ and (pilot_ $E_c/I_0)_2$ are the received pilot E_c/I_0 from AP_1 and AP_2 respectively; D is the hysteresis margin.

In the case of soft handover, shown as (b) in Fig. 4, before (pilot_ $E_c/I_0)_2$ goes beyond (pilot_ $E_c/I_0)_1$, as long as the soft handover trigger condition is fulfilled, the mobile enters the soft handover state and a new link

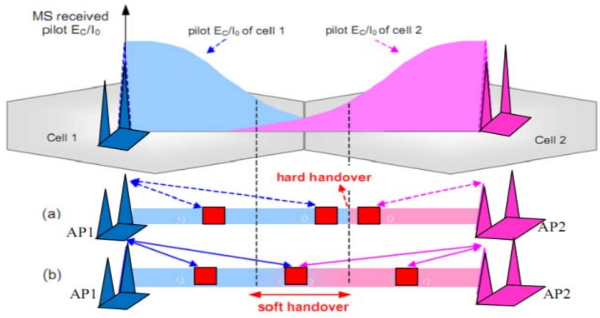

Fig. 4 Comparison between hard and soft handover.

is set up. Before AP_1 is dropped (handover dropping condition is fulfilled), the mobile communicates with both AP_1 and AP_2 simultaneously. Therefore, unlike hard handover, soft handover is a process of "make before break".

2.2 Algorithm of Soft Handover

The soft handover procedure can be divided into three phases: measurement, decision and execution phases as illustrated in Fig. 5.

In the measurement phase, the necessary information needed to make the handover decision is measured.

In the decision phase, the measurement results are compared against the predefined thresholds and then it is decided whether to initiate the handover or not.

In the execution phase, the handover process is completed and the relative parameters are changed, according to the different types of handover.

The performance of soft handover is related closely to the algorithm. Fig. 6 shows the soft handover algorithm:

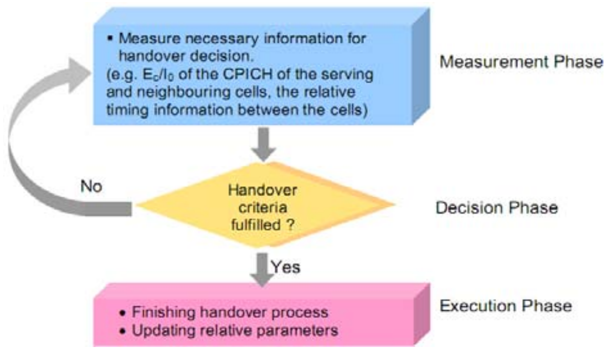

Fig. 5 Soft handover procedures.

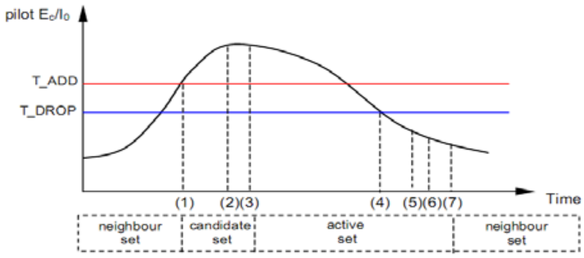

Fig. 6 Soft handover algorithm.

(1) Pilot E_c/I_0 exceeds T_ADD, Mobile node sends a Pilot Strength Measurement Message (PSMM) and transfers pilot to the candidate set.

(2) AP sends a Handover Direction Message (HDM).

(3) Mobile node transfers pilot to the active set and sends a Handover Completion Message (HCM).

(4) Pilot E_c/I_0 drops below T_DROP, Mobile node starts the handover drop timer.

(5) Handover drop timer expires. Mobile node sends a PSMM.

(6) AP sends a HDM.

(7) Mobile node transfers pilot from the active set to the neighbor set and sends a HCM.

The active set is the list of cells that currently have connections to the Mobile node; the candidate set is the list of cells that are not presently used in the soft handover connection, but whose pilot E_c/I_0 values are strong enough to be added to the active set; the neighboring **set** (monitored set) is the list of cells that the mobile continuously measures, but whose pilot E_c/I_0 values are not strong enough to be added to the active set.

(1) Advantages:

- Less the "ping-pong" effect, leading to reduced load on the network signaling and overhead.
- Smoother transmission with no momentary stop during handover.
- No hysteresis margin, leading to lower delay being equivalent to "instantaneous" macroscopic selection diversity.
- Reduced overall uplink interference, leading to better communication quality for a given number of users; more users (greater capacity) for the same required QoS.
- Fewer time constraints on the network. There is a longer mean queuing time to get a new channel from the target AP, this helps to reduce the blocking probability and dropping probability of calls.

(2) Disadvantages:

- More complexity in implementation than hard handover.
- Additional network resources are consumed in the downlink direction (code resource and power resource).

3. Soft Handover Optimization

The performance of the soft handover depends closely on the algorithm and the overhead. But in this section, a new method is proposed and the soft handover is optimized with the purpose of maximizing the downlink capacity.

The soft handover effects on the downlink are much more complicated than that on the uplink. In the uplink, soft handover does not lead to any extra consumption of resources because there is no extra channel needed. The macro-diversity gain offered by the selection combining in the wireless gateway brings benefits to both capacity and coverage. However, in the downlink, soft handover has two opposing effects. Macro-diversity gain offered by the maximal ratio combining in the mobile terminal benefits the system, but the extra resource consumed by the extra downlink channels increases the total downlink interference level. There is a trade-off between these two opposing effects and their combining effects decide the overall performance of the soft handover. In order to maximize the downlink capacity, the point where the macro-diversity gain overweighs the extra resource consumption needs to be found.

Wireless Mesh Network systems are interference limited, lower interference corresponding to higher capacity. Therefore, the basic principle for optimizing the soft handover in order to increase the downlink capacity is trying to minimize the interference brought by each user.

Using the user in Fig. 7 as an example, where P_{s1_1BS} is the power needed for guaranteeing the QoS when the user only has connection with AP1; P_{s1} and P_{si_2way} are the power needed from AP1 and APi respectively when the user is under 2-way soft handover; P_{s1_3way}, P_{si_3way} and P_{sj_3way} are the power needed from AP1, APi and APj respectively when the user is under 3-way soft handover. The total interference brought by the user to the system is the sum of the power of all the active downlink channels linked to it.

In order to minimize the interference and maximize the capacity, the decisions on whether to handover or not, and how many APs should be in the active set are made based on the comparison of the total resource consumption.

4. Optimized Power Control Strategy during Soft Handover

As mentioned in previous sections, Wireless Mesh Network systems are interference-limited. Minimizing the total interference is one of the basic rules for optimizing the radio resource in Wireless Mesh Network systems. The basic principle of the new power control approach is to minimize the total power consumption during the soft handover as lower power consumption means less interference to other active users.

Considering Mobile node in a two-way soft handover

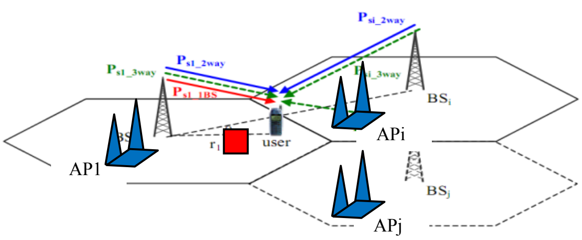

Fig. 7 Principle of the soft handover optimization.

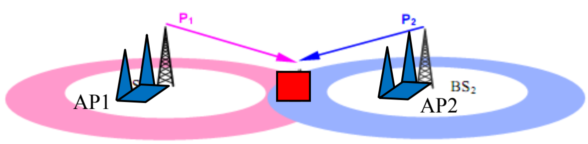

Fig. 8 Downlink power control during soft handover.

status as shown in Fig. 8, the total power consumed by this mobile is the sum of P_1 and P_2. P_1 and P_2 are the transmit power for the dedicated downlink channels from AP1 and AP2 respectively.

Assuming that load is distributed evenly within the system, the total transmit power of each AP is the same, denoted by P_T. After maximal ratio combining, the received bit energy-to-interference power spectral density radio E_b/I_0 of the mobile can be expressed as

$$\frac{E_b}{I_0} = \left[\frac{E_b}{I_o}\right]_1 + \left[\frac{E_b}{I_o}\right]_2 \tag{1}$$

With

$$\left[\frac{E_b}{I_o}\right]_1 = \frac{W}{?R}\frac{P_1 L_1}{P_T(1-a)L_1 + \sum_{i=2}^{M} P_T L_i} = \frac{W}{?R}\frac{P_1}{P_T\left(1-a+\sum_{i=2}^{M}\frac{L_i}{L_1}\right)} \tag{2}$$

And

$$\left[\frac{E_b}{I_o}\right]_2 = \frac{W}{?R}\frac{P_2 L_2}{P_T(1-a)L_2 + \sum_{\binom{j=1}{j\neq 2}}^{M} P_T L_j} = \frac{W}{?R}\frac{P_2}{P_T\left(1-a+\sum_{\binom{j=1}{j\neq 2}}^{M}\frac{L_j}{L_2}\right)} \tag{3}$$

Where W is the chip rate; R is the service bit rate; υ is the activity factor of the service; α is the downlink orthogonally factor; L_i is the propagation attenuation from APi to the mobile; M is the index of APs that are taken into account for the inter-cell interference. Substituting Eqs. (2) and (3) to Eq. (1) gives

$$\frac{E_b}{I_0} = \frac{W}{\nu R}\frac{1}{P_T}\left[\frac{P_1}{1-a+\sum_{i=2}^{M}\frac{L_i}{L_1}} + \frac{P_2}{1-a+\sum_{\binom{j=1}{j\neq 2}}^{M}\frac{L_j}{L_2}}\right] \tag{4}$$

Define a parameter B that represents the relationship between P_1 and P_2, as

$$B = \frac{P_{S_1}}{P_{S_2}} \tag{5}$$

According to the "no more, no less" principle, the received QoS of the mobile is kept as the target value. Thus, from Eqs. (4) and (5), the total power required by the mobile can be derived as

$$P_t = P_1 + P_2 = \left(1+\frac{1}{B}\right)\frac{\left(\frac{E_b}{I_o}\right)_t \frac{\nu R}{W} P_T}{\frac{1}{1-a+\sum_{i=2}^{M}\frac{L_i}{L_1}} + \frac{1/B}{1-a+\sum_{\binom{j=1}{j\neq 2}}^{M}\frac{L_j}{L_2}}} \tag{6}$$

Where $(E_b/I_0)_t$ is the target value for the service required by the user. From Eq. (6), it is clear that the total power consumed by the user is related to the power ratio B. Different ratios of P_1 to P_2 lead to different total power consumption. The aim of the new optimized power control strategy is trying to find the proper ratio B for minimizing the total power P_t.

5. Simulation [4]

There is a Mobile node traveling through the coverage areas of three APs (Fig. 9).

The simulations were done with some special speeds, such as: 5 m/s, 10 m/s, 40 m/s, 75 m/s (Fig. 10~Fig. 13).

As we can see, for the slowest speeds the overall length of the simulation time had to be increased in order to allow two handover. However, with the higher speeds (more than 40 m/s), the simulator seemed to handle the speed and there were no traffic problems between Mobile node and the AP, but in real life the situation would hardly be the same, or even possible to achieve.

Finally, for guaranteeing the handover performance, the speed should below 40 m/s because it is well above

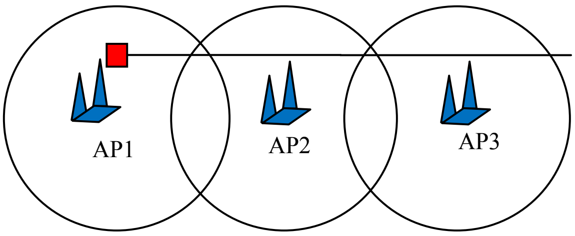

Fig. 9 Scenario.

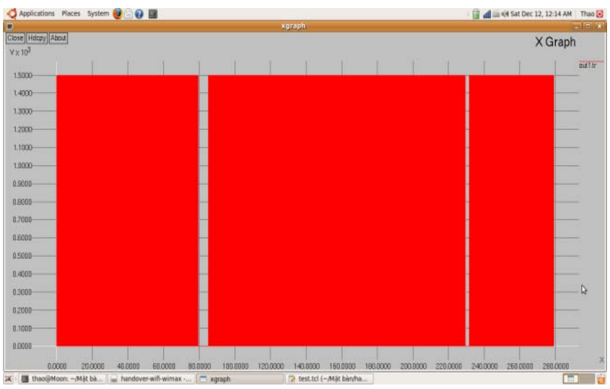

Fig. 10 HO with v = 5 m/s.

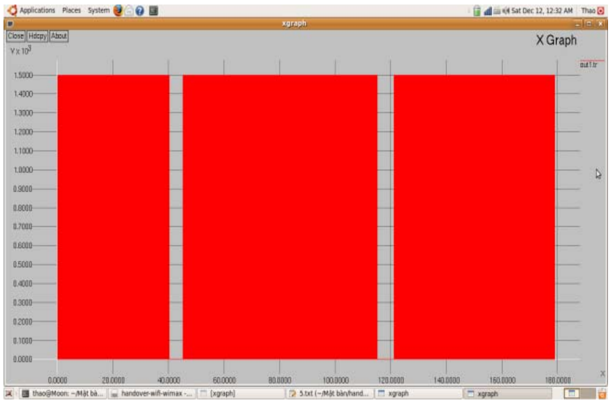

Fig. 11 HO with v = 10 m/s.

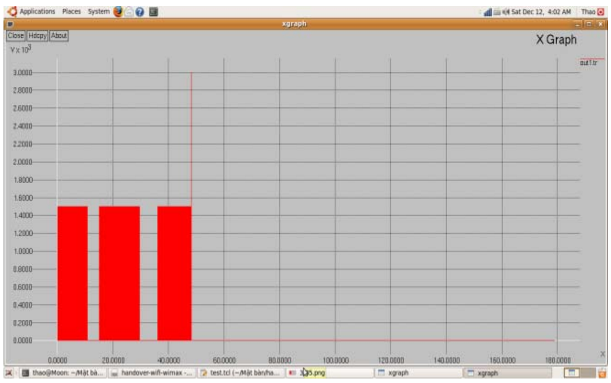

Fig. 12 HO with v = 40 m/s.

Fig. 13 HO with v = 75 m/s.

the mentioned 100 km/h "limit" for a seamless handover.

6. Conclusions

This paper introduces the soft handover concept and their advantages compared with the conventional hard handover. However, soft handover has the disadvantages of complexity and extra resource consumption. Therefore, optimization is crucial for guaranteeing the performance of soft handover.

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