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Selection of Dual Soft Handoff Leading to Improvements in Wireless Communication

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Abstract

In this paper we try to go through the different algorithms for handoff and select a combination of three emerging algorithms for Dual Soft Handoff. Moreover we go deeper into the actual workings of DSH with some results based on moments of Handoff

Keywords: Wireless Communication, Soft Handoff, Mobile Communication, Handoff Mechanics.

1. Introduction

With the development of wireless technology, wireless local area network (WLAN) and mobile communication have been penetrated into all aspects of our life. Roaming is the general topic for mobile nodes (MN). Because of the limitation of sending power and coverage, handoff is necessary and frequent when a MN roaming in WLAN. IEEE 802.11 deploys hard handoff. It disconnects with the current access point (AP) at first, and then connects to new AP. There is a handoff interval during which MN can't send or receive any data. There are many studies on how to diminish this interval or how to buffer data and resend them after reconnecting. But the existing interval may be intolerable for real-time applications such as video monitor system, voice over IP (VoIP) and kinds of alarm systems. With this we are trying to introduce a solution for eliminating the interval without data link and providing seamless data transmission during roaming with high speed.

2. Handoff Algorithms

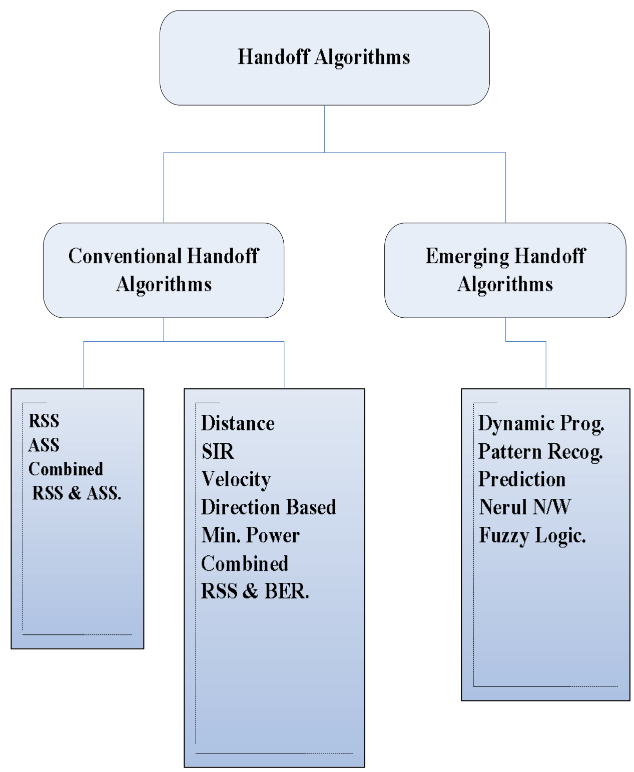


Fig 1: Handoff algorithm criteria

Conventional Handoff Algorithms.

Handoff algorithms are distinguished from one another in two ways, handoff criteria and processing of handoff criteria. Fig shows Handoff Algorithms at Glance.

Signal Strength Based Algorithms

There are several variations of signal strength based algorithms, including relative signal strength algorithms, absolute signal strength algorithms, and combined absolute and relative signal strength algorithms.

Relative Signal Strength Algorithms:

According to the relative signal strength criterion, the BS that receives the strongest signal from the MS is connected to the MS. The advantage of this algorithm is its ability to connect the MS with the strongest BS. However, the disadvantage is the excessive handoffs due to shadow fading variations associated with the signal strength. In many of the existing systems, measurements for candidate BSs are not performed if field strength for the existing BS exceeds a prescribed threshold. The disadvantage is the MS's retained connection to the current BS even if it passes the planned cell boundary as long as the signal strength is above the threshold. A variation of this basic relative signal strength algorithm incorporates hysteresis. For such an algorithm, a handoff is made if the RSS from another BS exceeds the RSS from the current BS by an amount of hysteresis.

Emerging Handoff Algorithms.

Dynamic Programming Based Handoff Algorithms:

Dynamic programming allows a systematic approach to optimization. However, it is usually model dependent (particularly the propagation model) and requires the estimation of some parameters and handoff criteria, such as signal strengths. So far, dynamic programming has been applied to very simplified handoff scenarios only. Handoff is viewed as a reward/cost optimization problem. RSS samples at the MS are modeled as stochastic processes. The reward is a function of several characteristics (e.g., signal strength, CIR, channel fading, shadowing, propagation loss, power control strategies, traffic distribution, cell loading profiles, and channel assignment). Handoffs are modeled as switching penalties that are based on resources needed for a successful handoff. Dynamic programming is used to derive properties of optimal policies for handoff. A signal strength based handoff as an optimization problem to obtain a tradeoff between the expected number of handoffs and number of service failures, events that occur when the signal strength drops below a level required for an acceptable service to the user. An optimal solution is derived based on dynamic programming and is used for comparison with other solutions. [26]

Pattern Recognition Based Handoff Algorithms:

Pattern recognition (PR) identifies meaningful regularities in noisy or complex environments. These techniques are based on the idea that the points that are close to each other in a mathematically defined feature space represent the same class of objects or variables. Explicit PR techniques use discriminate functions that define (n-1) hyper surfaces in an n-dimensional feature space. The input pattern is classified according to their location on the hyper surfaces. Implicit PR techniques measure the distance of the input pattern to the predefined representative patterns in each class. The sensitivity of the distance measurement to different representative patterns can be adjusted using weights. The clustering algorithms and fuzzy classifiers are examples of implicit methods. The environment in the region near cell boundaries is unstable, and many unnecessary handoffs are likely to occur. The PR techniques can help reduce this uncertainty by efficiently processing the RSS measurements.

Prediction-based Handoff Algorithms:

Prediction-based handoff algorithms use the estimates of future values of handoff criteria, such as RSS. Signal strength based handoff algorithms can use path loss and shadow fading to make a handoff decision. The path loss depends on distance and is determinate. The shadow fading variations are correlated and hence can be predicted. The correlation factor is a function of the distance between the two locations and the nature of the surrounding environment. The prediction based algorithm exploits the correlation property to avoid unnecessary handoffs. The future RSS is estimated based on previously measured RSSs using an adaptive FIR filter. The FIR filter coefficients are continuously updated by minimizing the prediction error. Depending upon the current value of the RSS (RSSc) and the predicted future value of the RSS (RSSp), handoff decision is given a certain priority. Based on the combination of RSSc and RSSp, hysteresis may be added if it will not affect the handoff performance adversely. The final handoff decision is made based on the calculated handoff priority.

Neural Handoff Algorithms:

Most of the proposed neural techniques have shown only preliminary simulation results or have proposed methodologies without the simulation results. These techniques have used simplified simulation models. Learning capabilities of several paradigms of neural networks have not been utilized effectively in conjunction with handoff algorithms to date. A signal strength based handoff initiation algorithm using a binary hypothesis test implemented as a neural network.

Fuzzy Handoff Algorithms:

The fuzzy handoff algorithm has shown to possess enhanced stability (i.e., less frequent handoffs). A hysteresis value used in a conventional handoff algorithm may not be enough for heavy fadings, while fuzzy logic has inherent fuzziness that can model the overlap region between the adjacent cells, which is the motivation behind this fuzzy logic algorithm. It incorporates signal strength, distance, and traffic. The methodology proposed in this paper allows systematic inclusion of different weight criteria and reduces the number of handoffs without excessive cell coverage overlapping. A change of RSS threshold as a means of introducing a bias is an effective way to balance traffic while allowing few or no additional handoffs. A combination of range and RSS modified by traffic weighting might give good performance. Different fuzzy composition methods to combine the cell membership degrees of different criteria methods can be adopted.

3. Dual Soft Handoff

The Dual-Soft-Handoff scheme discussed in this topic is shown in Fig. 5. Network B is a large network connected by switches and routers. MN is the mobile node which can transfer data with nodes in Network B through APs along the line. Each access point has two APs with directional antennas mounted back-to-back. $AP_{i,j}$ is the AP at point L_i, and j shows its antennas direction:

j=1: It's opposite with MN's moving direction;
j=2: It's the same with MN's moving direction.

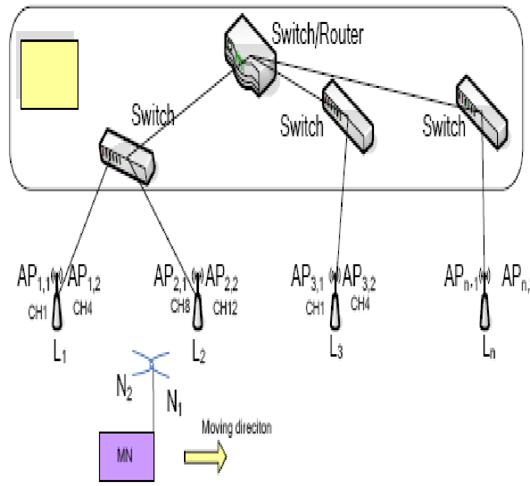


Fig 2: Soft-Dual-Handoff architecture

MN has two network cards (N_1, N_2) with directional antennas mounted back-to-back.
In topic, we put forward the Dual-Soft-Handoff scheme to support fast seamless roaming in WLAN.

When the MN moves from L_1 to L_2, it can receive signal from $AP_{0,2}$, $AP_{1,2}$, $AP_{2,1}$, and $AP_{3,1}$. The $RSS_{2,1}$ strengthens while $RSS_{1,2}$ lessens continuously. However, after the MN passes L_2, the $RSS_{2,1}$ falls to zero very quickly, and the $RSS_{1,2}$ keeps the link in a period of time. Therefore, N_1's handoff from $AP_{2,1}$ to $AP_{3,1}$ should be completed before arriving L_2. Data transfer is taken on by N_2 through $AP_{1,2}$ at this time.

When the MN arrives L_2, $RSS_{2,2}$ is at its maximum and N_2 can find $AP_{2,2}$. N_2 needs to switch to $AP_{2,2}$ before $RSS_{1,2}$ is under the threshold. The MN has connected with $AP_{3,1}$ by N_1, so data communication is held by N_1 and $AP_{3,1}$. Fig. 2 describes the general process of DSH during the MN roaming from L_i to L_{i+1}. It includes two phases.

Phase 1 is the forward handoff, and the new AP (NAP) is in front of the MN. It includes:
1) Data transfer between N_2 and $AP_{i,2}$;
2) N_1 switches from $AP_{i+1,1}$ to $AP_{i+2,1}$.

Phase 2 is the backward handoff, and the NAP is in back of the moving MN. It includes:
1) Data transfer between N_1 and $AP_{i+2,1}$;
2) N_2 switches from $AP_{i,2}$ to $AP_{i+1,2}$.

Here one network card's handoff occurs while the other works normally, so the data link can't be interrupted.

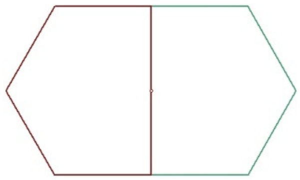


Figure 3 Directional attenuation's coverage

It includes two back-to-back APs. With directional antennas, AP's coverage is similar to a polygon, which is different from the omni-directional antenna.

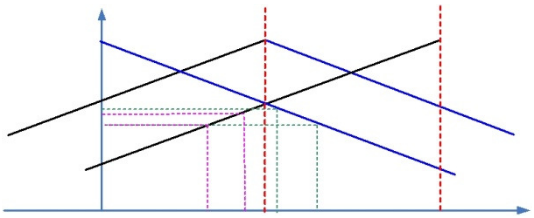


Figure 4 Receiving sig attenuation model of the MN

It describes the change of the signal strength of APs during the MN's moving. In Fig. 4, L_i is the location of AP; $RSS_{i,j}$ is the N_j Received Signal Strength of $AP_{i,j}$; T_i is the time MN passing L_i; t_1 is the time N_1 can switch; t_2 is the earliest time N_1 finishing switch; t_3 is the time N_2 beginning to switch; t_4 is the time N_2 must finish the switch; S_{min} is the threshold of N_1 to be able to probe a AP.

There are different policies to handle the handoff while passing L_2 from L_1:
1) MN finishes the handoff only before the original AP (OAP)'s signal reaches the connection threshold.
2)MN switches immediately when new AP (NAP)'s signal reaches the connection threshold.
If we adopt the former, it has some risk of N_1's handoff not fulfilling accidently. So we choose the latter: N_1 starts its handoff at t_1, just since probing $AP_{3,1}$'s signal; and N_2 also starts handoff at t_3($t_3 = T_2$) when receiving signal from $AP_{2,2}$. This policy can ensure both the handoff and the data communication.

4. Dual Soft Handoff Specifics

Handoff triggering time

Using the immediate handoff policy, it's clear that the backward handoff to be triggered when passing the access point. But the triggering time of forward handoff is worthy researching. Fig.5 illustrates N1 and N2's handoff model.

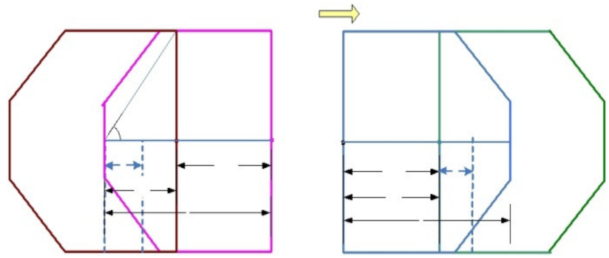


Figure 5. N_1's forward handoff and N_2's backward handoff

In Fig. 5, N_1/N_2 begin to switch at P_1/P_3, and finish switching at P_2/P_4; the distance needed for handoff is d; the distance from the switching point to the OAP is d_{th}; the distance between L_i and L_j is $D_{i,j}$; l is the AP's effective coverage; is the maximum deviation angle of MN's track.

Model for DSH

The program describes the major work of Soft-Dual-Handoff. It records moments and positions of handoffs, which are used to make later handoff trigger more accurately.

```
Dual_Handoff (int D_AB )
{ // N2 takes charge of data transfer with AP1,2
i = 1;
while ( dis_current() < D_AB ) { // D_AB=|AB|
if ( distance_fw () >= L_cov - distance_ap( i, i+1)
)
if ( probe(i, FW)==true) //find APi,1's signal
if ( trigger_handoff(N1, i, FW) == true) {
Handoff(N1, i, FW ); // N1's forward handoff
data_handover( N1 ); //N1 takes over data transfer
}
if ( distance_bk () >= distance_ap( i, i+1) )
if ( probe( i, BK) == true) // find APi,2's signal
if ( trigger_handoff(N2, i, BK) == true) {
Handoff(N2, i, BK ); // N2's backward handoff
```

data_handover(N2); //N_2 takes over data transfer

}i++;}}

Message flow in Dual Soft Handoff

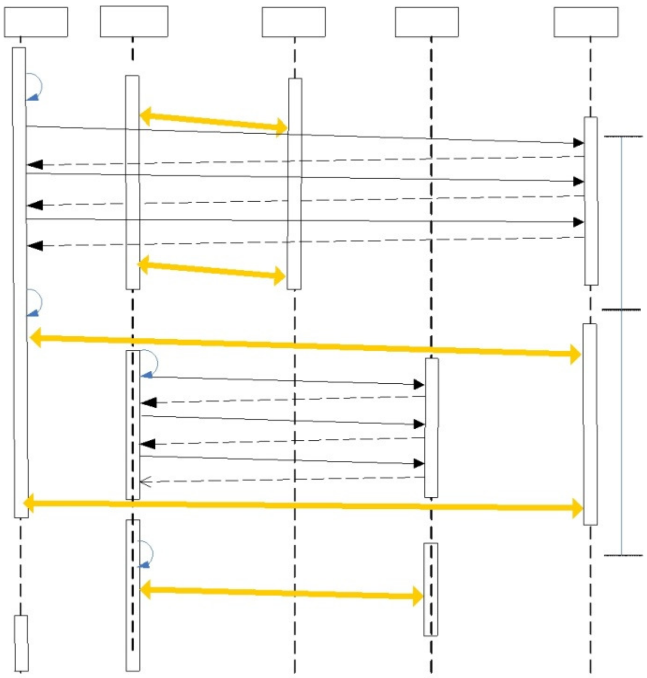


Figure 6 Message Flow in Dual Soft Handoff

Equations pertaining to DSH

If MN's velocity is *(t)* and passes the distance *d(t)* in a period of t ($\tau_1 \le t \le \tau_2$). The distance *d(t)* can be denoted as:

$$d(t) = \int_{\tau_1}^{\tau_2} v(t)dt \qquad (1)$$

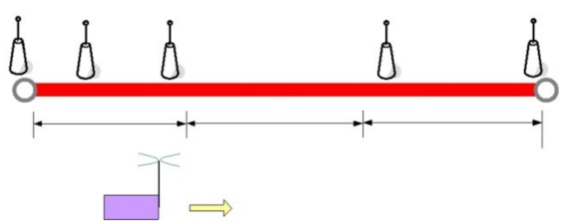


Figure 7 MN running at different speed in three stages

Fig is supposing that MN moves from station A to B, it goes through three stages: accelerating with the acceleration a_1; moving with even speed; decelerating with the acceleration $-a_2$. So we can get $v(t)$ and $d(t)$:

$$v(t) = \begin{cases} v_0 + a_1 t = a_1 t & (v_0 = 0, t \in [\tau_0, \tau_1], a_1 > 0) \\ v_{max} & (\tau_2 \in (\tau_1, \tau_2)) \\ v_{max} - a_2 t & (t \in [\tau_2, \tau_3], a_2 > 0) \end{cases} \qquad (2)$$

$$d(t) = \begin{cases} \frac{1}{2} a_1 t^2 & (t \in [\tau_0, \tau_1], a_1 > 0) \\ v_{max}(\tau_j - \tau_i) & (\tau_2 \in (\tau_1, \tau_2)) \\ v_{max}(\tau_j - \tau_i) - \frac{1}{2} a_2 t^2 & (t \in [\tau_2, \tau_3], a_2 > 0) \end{cases} \qquad (3)$$

If the MN moves with the deviation direction , the distance is *d*.

$$d \le d(t) \sec \beta, \beta \in [-\theta, \theta] \qquad (4)$$

$$d \ge d(t) \cos \beta \qquad (5)$$

When $d = d(t) \cos \beta \ge d(t)$, d is the minimum distance for successful handoff in the direction of APs and $d_{max} = d(t)$.

We can get d_{th-N_1} and d_{th-N_2} from fig. which can be amended by history data:

$$d_{th-N_1} = l - D_{i,j}, \quad d_{th-N_1} = D_{i,j} \qquad (6)$$

5. Results And Performance Analysis

According to the above analysis, we need to verify whether the Dual-Handoff model runs correctly. We designed a program to simulate the moving mode of MN. The simulation refers to some settings of subway data communication environment. It is supposed that the MN moves on the constant acceleration with the maximum velocity v_{max}. $T_{hj,i}$ is the time N_j begins to handoff from $AP_{i,j}$ to $AP_{i+1,j}$; $T_{cj,i}$ is the time N_j connects to $AP_{i+1,j}$; Data transfer between N_j and $AP_{i+1,j}$ until $T_{dj,i}$. To reduce the interference, channel 1, 8 assign to $AP_{0,2}$ and $AP_{1,2}$; channel 4, 11 assign to $AP_{1,1}$ and $AP_{2,1}$, and so on.

Moments

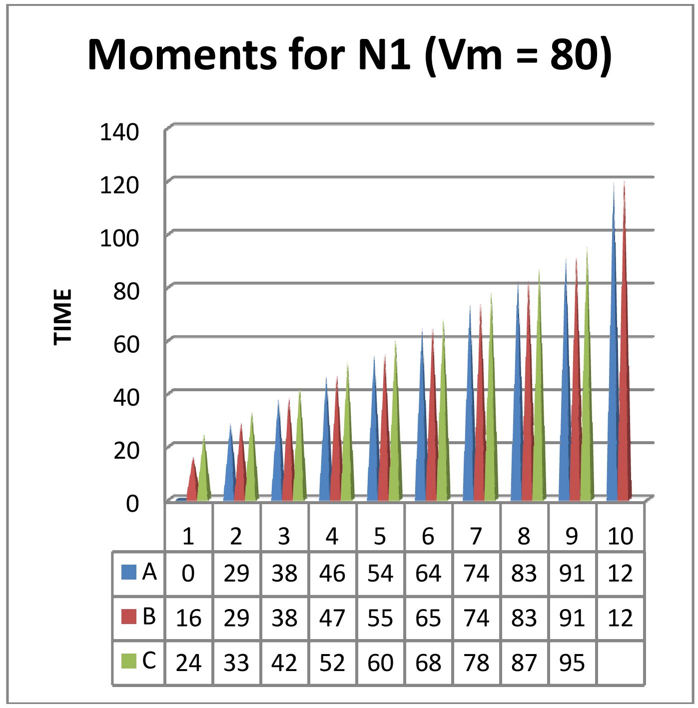
Table 5.1: Different Parameters involved with meanings, values and units

Parameter	Meanings	Value	Unit
	Distance between A and B	2000	m
	Distance between adjacent APs	170 - 230	m
L	Coverage of each AP	300	m
	MN's maximum velocity	60/80/120	Km/h
	Accelerating/Decelerating Time	30/40	s
	Handoff Time	300	ms

Table 5.2: The Moments of Dual Soft Handoff (for 80km/h)

V_{MAX}=80KM/H, T_A=30S, 170M< $D_{I,J}$ = D_{TH_N2}< 230M, 70M<D_{TH_N1}<130M

I	N1(s)			N2(s)		
1	15.76	16.06	24.22	23.92	24.22	28.86
2	28.56	28.86	32.94	32.64	32.94	38.16
3	37.86	38.16	42.39	42.09	42.39	46.71
4	46.41	46.71	51.66	51.36	51.66	54.59
5	54.29	54.59	60.21	59.91	60.21	64.71
6	64.41	64.71	68.09	67.79	68.09	73.85
7	73.55	73.85	78.21	77.91	78.21	82.80
8	82.50	82.80	87.35	87.05	87.35	91.45
9	91.15	91.45	95.12	94.82	95.12	120.00
10	120.00	120.30				



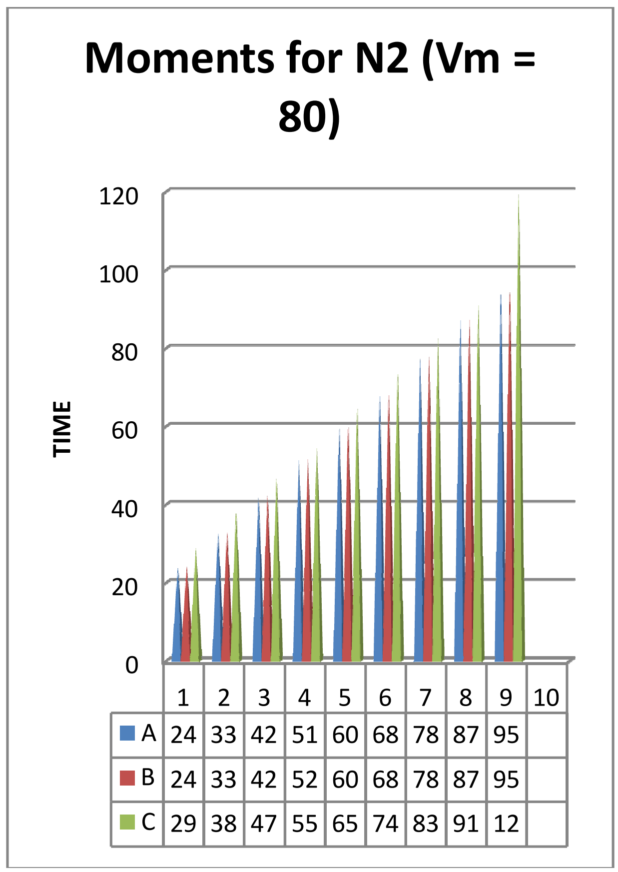
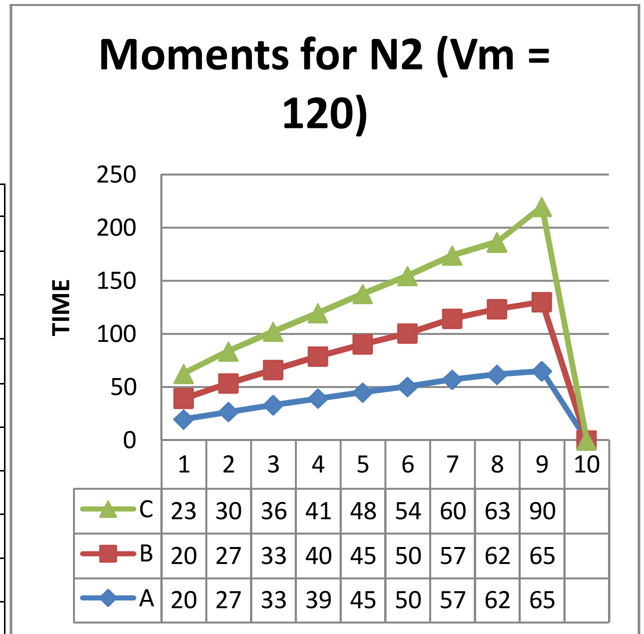
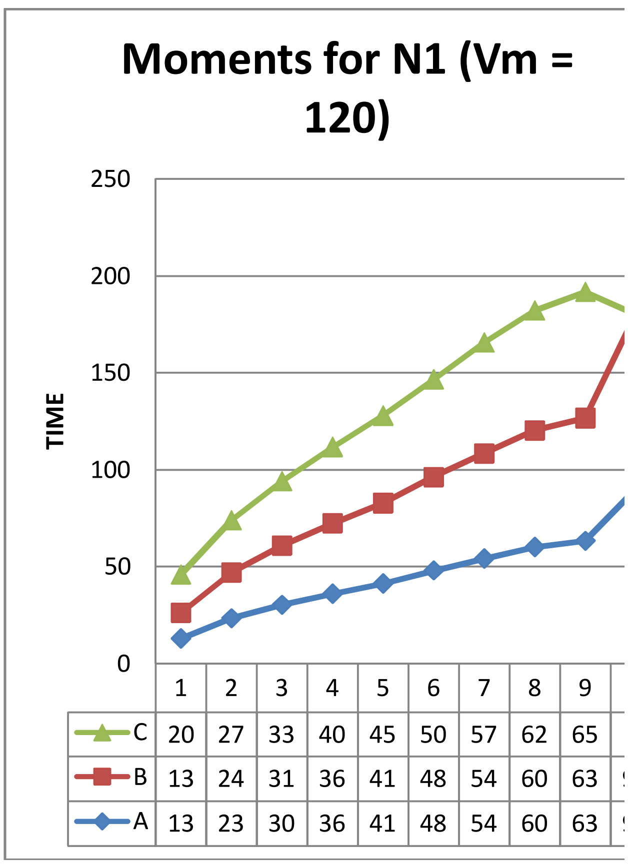


Table 5.3: The Moments of Dual Soft Handoff (for 120km/h)

V_{MAX}=120KM/H, T_A=30S, 170M< $D_{I,J}$ =D_{TH_N2}< 230M, 70M<D_{TH_N1}<130M

I	N1(s)			N2(s)		
	$T_{h1,i}$	$T_{c1,i}$	$T_{d1,i}$	$T_{h2,i}$	$T_{c2,i}$	$T_{d2,i}$
1	12.87	13.17	19.83	19.53	19.83	23.32
2	23.32	23.62	26.86	26.56	26.86	30.24
3	30.24	30.54	33.36	33.06	33.36	35.94
4	35.94	36.24	39.54	39.24	39.54	41.19
5	41.19	41.49	45.24	44.94	45.24	47.94
6	47.94	48.24	50.49	50.19	50.49	54.03
7	54.03	54.33	57.24	56.94	57.24	60.00
8	60.00	60.30	61.86	61.56	61.86	63.17
9	63.17	63.47	65.16	64.86	65.16	90.00
10	90.00	90.30				





From Tab. 5.2 to Tab. 5.3, we can find that:

$$T_{c1,i+1}, T_{c2,i} = T_{d2,i}, T_{d1,i} \quad \dots(7)$$
$$T_{h1,i+1}, T_{h2,i} > T_{c2,i}, T_{c1,i} \quad \dots(8)$$

These mean that one network card's data link maintains until another ready to built new data link; and the handoffs won't happen simultaneously. Therefore, the SDH can provide seamless connection during MN's fast roaming.

6. Conclusion

The proposed Soft-Dual-Handoff scheme aims at providing high quality data link for the rapid motion nodes.

It has high reliability, which is important for applications such as subway control, video or audio transmission.

If one link is broken- down, the SDH switch automatically to single network card mode, which can earn time for resuming from failure.

The SDH requires only the cooperation of mobile nodes, and AP needn't any modification. Therefore, AP can adopt standard IEEE 802.11 serial products to save investment.

In fast MSs, a handoff occurs frequently in WLANs due to their small coverage area. It implies that the frequency of handoff s will increase especially in WLANs, so a large number of handoff requests must be handled. Therefore, the handoff dropping probability is increasing, and the service quality (e.g., GoS) becomes worse. On the other hand, the CDMA system is large enough to accommodate fast MSs, and lower handoff request rates, thus resulting in lower burden and good service quality. It is safe to assume that either slow or stationary MSs transmit more data and that fast moving stations communicate at lower data rates. Therefore, according to the MS speed, the load balancing handoff between WLAN and CDMA results in good service quality and the avoidance of unnecessary handoff s. Our proposed methods adopt the mobility management concept through the MS speed cost function to minimize the GoS.

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