A Novel Handoff Algorithm Of Wireless Communication For Multi-tier IP-based Network

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Abstract:

Most of multimedia services were provided by Internet. The developments of wired network technologies are significant rapidly, such as the IP-based network. These technologies can be used to develop wireless communication network directly. The combination of wired network and wireless network could be used to access data mutually. In this paper, the multi-tier architecture is based on IP network. Recently, there are many communication systems brought up in order to offer every state's mobile users with the best services. However, mobile users are not always in the same state. In economic benefits, it's very inconvenience, if one uses more than one system, he should carry more than one MH at the same time. Therefore, combining all systems in a multi-tier IP-based network and disposing stratum dynamically for mobile user become a solution of such situation. Besides, we hope to reduce the frequency of handoff and increase the using rate of resource in multi-tier architecture. Therefore, in this paper, a handoff algorithm of Multi-tier IP-based network has been brought up for wireless communication. The handoff algorithm of multi-tier wireless communication is divided into two parts that are old-tier and new-tier priority algorithm. Making the programs for simulating, and then making sure that the algorithm is workable and modifying the algorithm. The results of simulation show 11.99% of handoff

frequency has been decreased and 8% of using rates of resource has been increased.

Keyword: handoff, multi-tier IP-based network, multi-tier, mobile host（MH）, new-tier, old-tier

1. Introduction

In the recent year, the number of mobile users has increased much faster than anticipated. According to the Universal Mobile Telecommunication System (UMTS) Forum, there will be around 1800 million mobile users worldwide in the year 2010. [1] Under the situation that limited resources and more and more users, handoff algorithm becomes very important for mobile users remove seamlessly of wireless communication.

There are many communication systems brought up to provide mobile users with the best services. For example, cellular IP is suitable for indoor or pedestrian environment; Mobile IP is suitable for vehicle environment and satellites communication system is suitable for boat or plane environment. To aid users in connecting wireless communication network anywhere, the multi-tier IP-based network that presented by ITU is imperative. The multi-tier IP-based network is the combination system of covering different region and supporting different transmitted speed of network.

In this paper, a handoff algorithm is addressed for multi-tier IP-based network. We hope to decrease the time of handoff, increase the use of resource and make users always in the best state.

The paper is structured in following statement. In section 2, some background information will be introduced. In section 3, the algorithm will be described by using flow-chat. In section 4, simulations and analysis will be revealed, and the conclusion is listed in section 5.

2. Background

- Mobile IP

  The Internet Engineering Task Force (IETF) was formed at Columbia University. John Ioannidis and Gerald Maguire Jr. originally organize the

team and proposed Mobile IP, which defined two substantive, home agent (HA) and foreign agent (FA), to manage MHs in the internet in June of 1992. [2]

- Proper noun [3]
  i. Home agent (HA) ： A base station (BS) that there are data for register for the MH in his database.
  ii. Home network ： The network which includes the HA is call home network.
  iii. Home address ： To show the place of the MH and to be distributed by the HA.
  iv. Foreign agent (FA) ： A BS which is not HA.
  v. Foreign network ： The network which includes the FA.
  vi. Care-of address ： A care-of address shows the temporary place of the MH and is distributed by the FA.
- Register [4][5][6][7]

If a MH were in home network, it would register at home agent. If this MH came to a foreign network, FA would send an advertisement message to HA to check the existence of MH. If the MH existed in HA, MH would send a registration request message to the HA through the FA. The HA will reply a registration reply message to the FA. Figure 1 shows the register in mobile IP system.

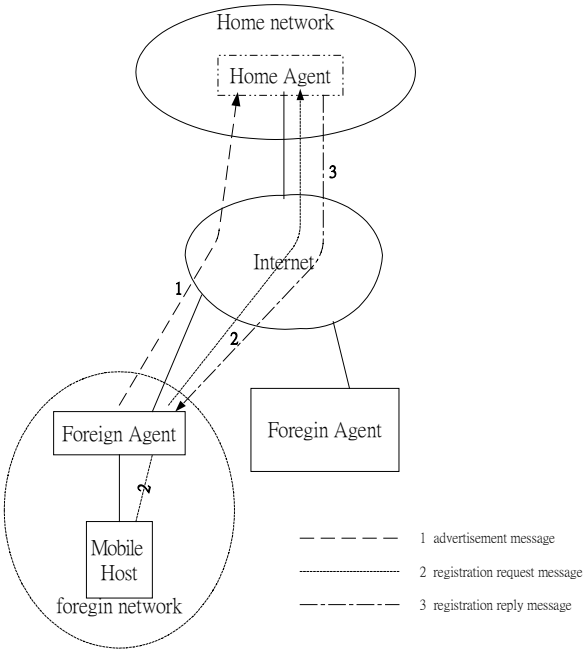

Figure 1: register in Mobile IP

- Data transmission

If data packets were send to MH that is in home network, the packets would transmit it to home

address directly. If data packets were send to MH that is in foreign network, the packets would transmit it to HA first. HA transmits the packets to FA by the care-of address, and then the FA transmits the packets to the MH. If MH had data to transmit for the other MH, they would transmit by the home address directly.

- Cellular IP

Mobile IP is not suitable for fast mobility, because MH must register continuously to a possible long-distanced HA continuously after a local migration. Cellular IP provides fast and smooth handoff for local migration. Figure 2 shows the handoff in cellular IP. MH needs to request handoff when MH moves from old BS to new BS. It will send routed-update-message to the crossover BS and without registration to HA again. Then, BS 1 keep the record of MH is in new BS, BS 2 keep the record of MH is in BS 1,and crossover BS keep record of MH is in BS 2. Then, the crossover BS notifies the record of about the MH has changed the position. Data packets will be transmitted to BS 2, after crossover BS keep the record of the MH is in BS 2.

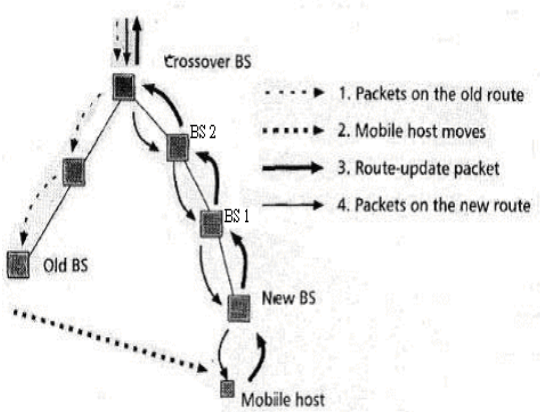

Figure 2:data transaction of Cellular IP

Before handoff succeeded, if data packets were sent to MH, the packets would be send to old BS. The data packets would not lost, because of the cell overlaps. MH still can receive the data packets from the old cell. [8][9][10][11]

- Satellite system [12]

The commercial use of satellites for mobile communications began with the COMSAT/MARISAT

system in1976. Satellites are sorted to different class. They are geostationary orbit (GEO) and medium earth orbit (MEO) and low earth orbit (LEO). Table 1 shows the comparison of them.

	GEO	MEO	LEO
Number of satellites for cover the earth	3-4	10-15	40-70
Operational complexity	Low	Medium	High
Frequency coordination complexity	Medium	High	High
Transmission delay (ms)	370	220	140-220

Table 1: Comparison of orbits for satellite communication system

The system should be without being delayed because real-time data is very important for the third generation （ 3G ） wireless communication. However producing satellite is very expensive. In order to cover the earth, numbers of LEO satellite is necessary. How to keep the balance? Thus many satellite communication systems were proposed.

The first generation satellite communication system began from 1998 because there are two large improvements. One is the minimal of terminal size and the other one is frequency reused. Table 2 shows the several systems of satellite communication system in the first generation.

Parameter	Iridium	Globalstar	ICO	Aires
Number of satellite	66	48	10	46
Satellites per orbit plane	11	8	5	5 in each inclined orbit 11 in equatorial orbit
Voice bit rate	4.8	1-9	4.8	2.4
Multiple access	TDMA-FDMA	CDMA-FDMA	TDMA-FDMA	CDMA-FDMA
Nominal capacity per satellite	1100	2400	4500	?

Table 2:several system of satellite communication system

- Multi-tier

The International Telecommunication Unit (ITU) proposes the concept of multi-tier, to combine all manners of wireless communication and provide a standard in different systems of wireless communication. The multi-tier will be used in third generation wireless communication.

A multi-tier cell contains four stratum and bigger cell covers smaller cell. (See figure 3) There is a connect switch subsystem (CSS) in each cell. CSS is to play the role of bridge, to connect with every cell. It means the switch of data packets and data of recognition are delivered by CSS.

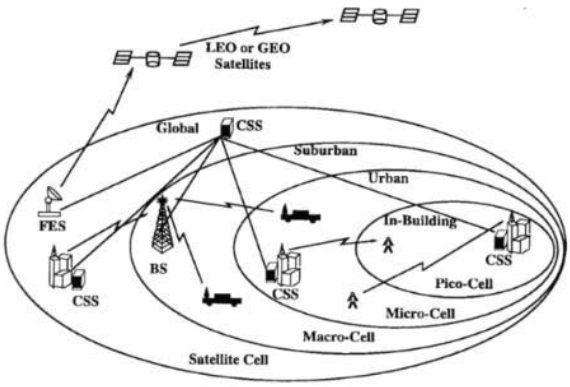

Figure 3: Framework of multi-tier network

Users of indoor or pedestrian or in low-speed users are in pico-cell or micro-cell, and they will use the cellular IP system and the speed of data transmission is in 2MB/s. Users of vehicle or in high-speed users are in macro-cell, and they will use the Mobile IP system and the speed of data transmission is in 384KB/s. Users of boat or plane or in higher speed are in satellite cell, and they will use the satellite communication system and the speed of data transmission is in 4.8KB/s.

3. Handoff Algorithm Of Multi-tier

- To classify stratum

According to the state of MHs, MHs be divided into the four kinds of cell. Table 3 shows the parameter of a multi-tier cell.

Cell	Speed of data transmission	Radius of cover	Range of it's speed (km/hr)
Pico-cell	<5M/S	5M	<5
Micro-cell	<2M/S	1KM	5 ~30
Macro-cell	<384KB/S	35KM	30 ~200
Satellite-cell	<4.8KB/S	100~500KM	>200

Table 3: to classify stratum

- Algorithm

MH will request a handoff, as it will go out the range of BS's signal. In this paper, mobile controlled handoff (MCHO)[13] and soft-handoff are the main framework of research. Traditional handoff algorithm is modified to achieve the request of handoff.

In this paper, when a mobile host (MH) requests a handoff, MH is allotted different stratum dynamically according to the speed of MH and the request of resource. The algorithm will determine to change the stratum or not when the MH requests the handoff. If the speed or resources isn't suitable the MH, the stratum should be changed. The algorithm will be active working, the workable process of algorithm is called new-tier priority algorithm. If the stratum won't be changed, it work algorithm, which is called old-tier priority algorithm. Combining the two algorithms to one, that is our multi-tier handoff algorithm.

i. New-tier Priority Algorithm

MH checks the signal from the new-tier BSs when it determines to change the stratum. To permute the strength of signal from new-tier-1's BSs from the strong stage to the weak stage, and then to ask for resource from the strongest signal BS. It will handoff, if the BS has enough resource for the MH. If not, MH will ask resource for the second stronger signal BS. Moving in circles until handoff succeeds. If all of BSs have not enough resource, MH checks the signal from new-tier-2's BS from the strong stage to the weak stage. New-tier-2 means that higher than new-

tier-1. Example one, Pico-cell is old-tier of the MH A. New-tier-1 is micro-cell of MH A, if MH A increase the speed. And then, new-tier-2 is macro-cell of MH A. Example two; old-tier is macro-cell of the MH B. New-tier-1 is micro-cell of MH B, if MH decreases the speed. And then, new-tier-2 is Pico-cell of MH B. Example three; old-tier is macro-cell of the MH C. New-tier-1 is satellite cell of MH C, if MH C increases the speed. And then, there is no new-tier-2 of MH C. MH asks for resource from new-tier-2's BS, when the new-tier-1 doesn't satisfy the MH. Moving in the same circle in the new-tier-1, until handoff succeeds. If all BS of new-tier-2 didn't have enough resource for MH, MH would request resource from old-tier's BS and move the same circle in the new-tier-1, until handoff succeeds. If all BS of old-tier didn't have enough resource, the request of handoff from the MH would be rejected.

It just has four stratums in each multi-tier cell. It will not be suitable for the MH, if we across too much stratum for the MH. So MH just has new-tier-2. The flow-chart of algorithm shows as figure 4.

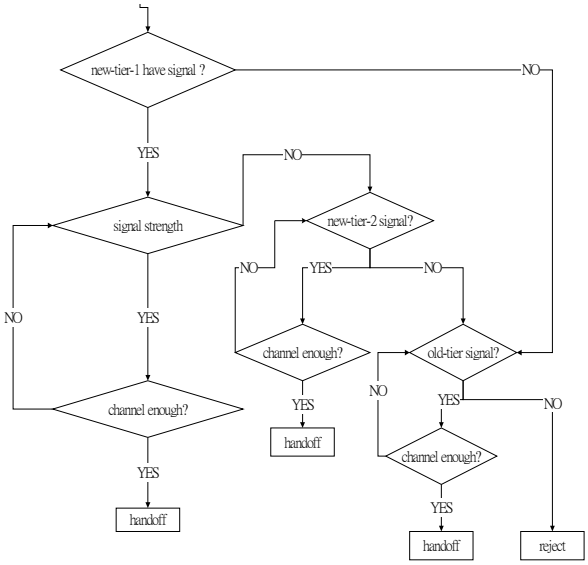

Figure 4: new-tier priority algorithm

ii. Old-tier Priority Algorithm

It works the old-tier priority algorithm and checks the signal strength from the same tier when it doesn't to change stratum. To permute the signal strength of BSs from the strong stage to the weak stage, and then ask for the resource from the strongest signal BS. It will handoff if the BS has enough resource. If not, MH asks for resource from the second stronger signal BS. Moving in circles until handoff succeeds. If all of BSs have not enough resource, MH checks the signal from new-tier's BS from the strong stage to the weak

stage. New-tier means that speed of MH A is closer to old-tier based on the range of speed. For example, speed of MH A is in 32 km/hr. Macro-cell is old-tier of the MH A. Micro-cell is New-tier of MH A. MH requests resource from new-tier's BS, when the old-tier can't satisfy the MH. Moving the same circle in the new-tier, until handoff succeeded. If all BS of new-tier didn't have enough resource for MH, the request of handoff from the MH would be rejected. The reason is the same as above. The flow-chart of algorithm shows as figure 5.

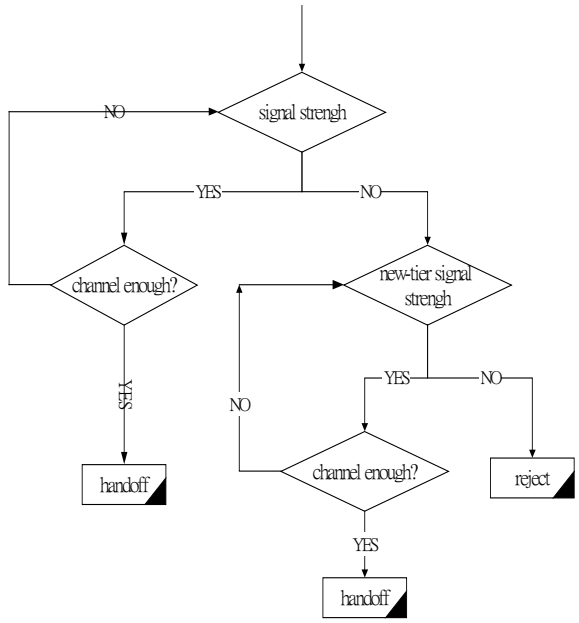

Figure 5 :old-tier priority algorithm

4. Simulation

- Simulate Circumstances

There are some assumptions for simulation of algorithm. The first, the cell is infinite. The maximum cell is satellite cell, which deliver data by satellite. The assumption is reasonable because only three GEO satellite can cover all the earth. The second, each cell has 5M resources. It means that a multi-tier cell has 20M resources. Table 4 shows that each cell transports data in a limited speed and limited cover range. According to pico-cell, each cell is assumed that each cell has 5M resources. The third, MH requests a handoff when it's moving distance more than the cell's diameter. In face, MH can move in any passage. Diameter is an average of move trajectory. The fourth, the top of speed is in 1000km/hr, because the speed of an aircraft is between 1000km/hr and 2500km/hr. It is too large of the range of specimen, if the range of speed is between 0km/hr and 2500km/hr. The fifth, the number of user in micro and macro-cell are more

than the number of users in pico-cell and satellite cell. So MHs's speeds in macro and micro-cell have larger weight. Then, the rate of user in pico-cell is 15% and in micro-cell is 37.5% and in macro-cell is 42.5% and in satellite cell is 5%. The simulation will more conformable to fact the reality.

Cell	Top of transport speed	Distance for handoff	Range of speed (km/hr)	Rate of user
Pico-cell	5M/S	10M	<5	15%
Micro-cell	2M/S	2KM	5 ~30	37.5%
Macro-cell	384KB/S	70KM	30~200	42.5%
Satellite-cell	4.8KB/S	200KM	200 ~1000	5%

Table 4： compares of multi-tier

We have four programs in C++ to simulate the algorithms.

I. Simulation for handoff

There are forty MHs in multi-tier network. The system gives random time T [i] and random speed S [i] for each MH. MH's stratum is allocated according S [i]. It means that MH i will in micro-cell if S [i] lower than 30km/hr. And i moves in the speed S [i] during time T [i]. After the time T [i], the MH moves on distance D [i]. MH ask for a handoff when D [i] over the distance of diameter and add one to handoff variable H. MH i get a new time T [i]' after T [i]. Moving in circles for one hour and to record the times of handoff of forty MHs. Time continued to count two, three …until ten hours and record them. There are some differences between the two programs for handoff simulation. One of the two programs is for the experimentation and the other is for the comparison. After handoff, MH i will change its stratum in new speed S [i]' in experimentation. After the first stratum allocation, the stratum will not change in comparison. Working the two programs ten times. The number will be deleted when it has much difference with the others. The average of the rest numbers is the result.

Why the number of MH is forty? If the number of the MH is large than forty, the variable of times accumulation in handoff will overflow. During ten times of working program it just has two times overflowed in 40 MHs. So, the number of MH is forty. The result would be deleted if the variable overflowed.

II. Simulation for the rate of resource used

There are one hundred MHs in a multi-tier cell. System gives random time T [i] and random speed S [i] and random resource R [i] for each MH. MHs' stratum is allocated by S [i] and requests the resource R [i] from the cell's BS. If the BS has the resource R [i], MH i will be served. Else MH i will be rejected in comparison. But, the MH will to change stratum and request the resource R [i] from the new-tier again in experimentation, according to the old-tier priority algorithm. When handoff succeeded, the variable u[i], which is show the used of resources, will be added R [i]. Until one hundred MHs achieve the request of resource and then recording the rate of resource used. Increasing the number of MH to 200,300…1000 and then record its rate of resource used. Working the two programs ten times, the number will be deleted when it has large difference with the others. Averaging of the rest numbers, it is the result.

- ANALYSIS

Frequency \	0	1	2	3	4	5	6	7	8	9	Average
1	29675	91814	67823	64176	52683	73951	35718	74481	43062	43563	57695
2	70309	174745	143017	120174	91263	136883	67977	150020	94382	93603	114237
3	112260	247154	217678	165754	127348	191085	96861	236492	146566	120389	166159
4	155886	349976	287467	201436	161634	244097	119345	318095	207007	146087	219103
5	200292	462199	357799	219981	198815	297906	141457	395703	267979	177495	271963
6	265131	553968	440613	232928	224423	344261	163266	475584	314552	225941	324067
7	320554	665905	492349	257114	254893	386723	198225	545397	363943	272230	375733
8	366901	756867	520767	288236	301419	419851	243191	602649	414340	326262	424048
9	413275	855768	542330	324278	359605	441324	299748	656181	480218	383158	475589
10	455805	974208	572609	366788	414599	455045	361954	715765	548236	445804	531081

Table 5: Frequency of handoff in experimentation

Frequency \	0	1	2	3	4	5	6	7	8	9	Average
1	49126	48648	35193	47514	78053	48407	84729	84729	41866	46909	55102
2	98222	97303	65158	95055	173287	111927	172755	172755	118615	93847	116838
3	147366	118431	95377	140154	246892	221147	302031	302031	187573	146407	178371
4	201746	175734	125529	189759	384647	330622	405353	405353	256839	165689	248866
5	256366	280785	152405	247643	513939	390585	436699	436699	345101	184902	306444
6	311792	312853	213390	346112	665129	504113	536260	536260	440197	225078	383384
7	324278	404935	262145	442749	772385	601876	636001	636001	501790	273843	452552
8	355515	490992	310738	479968	856005	679879	725236	725236	562087	279223	515731
9	398383	580098	401510	607676	880619	831107	828911	828911	613273	303682	602092
10	449165	720248	429290	692917	890507	904822	883972	883972	677870	339187	672644

Table 6:Frequency of handoff in comparison

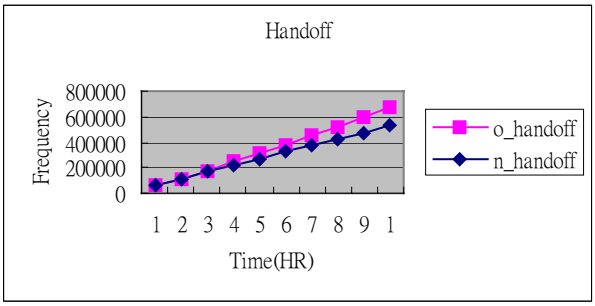

Figure 6:diagram of curves for comparatively for handoff

Table 5 shows the number of handoff in experimentation. Table 6 shows the number of handoff in comparison. To permute the data in table 5 and table 6 increasingly, it can be find that the result in the first two hours in comparison is better than in experimentation, sometimes. Observing the time of MHs in the first random time in experimentation and comparison. It can be found that the time is longer than one or two hours. It means that the MH in the best state in the first random time in comparison, because they are distributed in the best state in the first time.

According to the table 5 and table 6 the new-tier priority algorithm throughput performance is 11.99%, it is better than the traditional algorithm. It means that the new-tier priority algorithm can reduce 11.99 times for per 100 handoffs. Figure 6 shows a diagram of curves of an average for comparison. The X axle shows the times of handoff and Y axle shows the hours for handoff.

MH#	Rate 0	Rate 1	Rate 2	Rate 3	Rate 4	Rate 5	Rate 6	Rate 7	Rate 8	Rate 9	Average
100	98.33	94.89	98.42	96.27	93.65	96.61	98.055	98.87	97.865	98.005	96.979
200	99.68	98.67	98.75	99.52	99.595	98.6	98.405	99.4	99.37	98.87	98.993
300	99.68	99.74	99.61	99.67	99.855	99.175	99.565	99.845	99.45	99.62	99.588
400	99.78	99.74	99.78	99.88	99.9	99.805	99.685	99.985	99.72	99.77	99.773
500	99.95	99.88	99.90	99.88	99.92	99.805	99.895	99.985	99.76	99.85	99.871
600	99.97	99.88	99.90	99.88	99.945	99.895	99.905	99.985	99.76	99.93	99.899
700	99.97	99.89	99.90	99.88	99.965	99.905	99.905	99.985	99.76	99.965	99.908
800	99.98	99.89	99.93	99.88	99.965	99.905	99.96	99.985	99.845	99.975	99.932
900	99.98	99.89	99.93	99.88	99.965	99.91	99.96	99.985	99.94	99.995	99.947
1000	99.98	99.89	99.93	99.92	99.965	99.93	99.975	99.985	99.94	99.995	99.951

Table 7:rate of resource used in experiment

MH#	Rate 0	Rate 1	Rate 2	Rate 3	Rate 4	Rate 5	Rate 6	Rate 7	Rate 8	Rate9	Average
100	86.885	66.625	81.13	74.105	69.41	72.475	98.365	85.715	68.89	54.83	73.245
200	88.945	82.515	81.41	97.335	74.65	72.475	98.61	88.24	69.08	72.54	78.732
300	89.48	88.065	87.845	99.245	75.815	94.835	98.65	89.025	72.335	83.945	85.168
400	89.48	91.915	87.91	99.42	92.505	95.66	99.03	89.025	93.76	96.755	92.126
500	94.78	91.915	97.655	99.465	92.585	97.11	99.185	92.345	98.36	97.465	95.277
600	98.95	94.895	99.11	99.465	92.6	97.11	99.5	95.075	98.41	98.835	96.873
700	98.96	98.52	99.11	99.475	92.6	97.11	99.595	98.815	98.61	99.545	97.909
800	99.085	98.52	99.155	99.475	95.605	97.11	99.615	99.295	98.61	99.585	98.371
900	99.085	98.55	99.155	99.475	95.605	97.96	99.705	99.47	98.76	99.77	98.544
1000	99.085	98.55	99.155	99.475	96.795	97.96	99.74	99.595	98.76	99.77	98.709

Table 8: rate of resource used in comparison

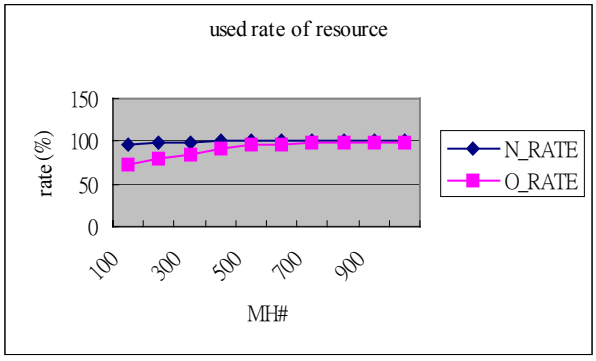

Figure 7: diagram of curves in comparatively for the rates of used of resource

Table 7 shows the rate of use in resource in experiment and Table 8 shows in comparison. The rate doesn't change as the MH's number are between 400 to 900 in the fourth executing of program (rate 3) in comparison. It is special condition, so we delete the result. The result that the eighth execute of program (rate 7) in comparison and the fourth execute of program (rate 3) in experiment, we have deleted them in the same reason. The rate in the seventh execute of program (rate 6) for one hundred MHs is too large than any other results in experiment. It is special condition, so we delete the result.

According to the table 7 and table 8 it can be found that the new algorithm throughput performance is 8% better than the old algorithm. It means that the new algorithm increase the use of resources. Figure 7 shows a diagram of curves of an average for comparison. The X axle shows the number of MHs and Y axle shows the rates of resources. When the numbers of MH over seven hundred, there is only little

improvement of the algorithm. The rate of used resources get to 98% in comparison. But it promotes 99% in experiment. No matter how much the number of MH, it can keep in high rate of used resource in our algorithm. But it will have high rate of used resource in comparative unless there are over six hundred of MHs.

5. CONCLUSION

Sometimes, the MHs changes state when MH ask for a handoff. For example, the increasing of speed in MH and the stratum is no more suitable for the MH. In this paper, the MH can change the stratum anywhere and any time to suitable for the MHs' speed in multi-tier IP-based network. It will reduce times of handoff. Sometimes, MH will be rejected because it does not have enough of resource. It can change the stratum to get resources. So the rate of used resource will increase, too. For this reason, the QoS is raised.

In this paper, a handoff algorithm of Multi-tier IP-based network is brought up for wireless communication. The algorithm is divided into new-tier priority and old-tier priority handoff algorithm two parts. Making the programs for simulating and make sure that the algorithm is workable. The results of simulation show the decreasing of 11.99% frequency in handoff and increasing 8% using rates of resource

In the future, resource reservation protocol (RSVP) will be used in multi-tier. Dynamical resource disposed for multi-tier is a very good issue. They will heighten the quality of service (QoS) for multi-tier IP-based network.

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