Understanding ICAM: Integrated Cellular and Ad Hoc Multicast

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ICAM(Integrated Cellular and Ad Hoc Multicast) is a method of improving multicast protocol within 3G network via use of WiFi (IEEE 802.11 network). In current 3G multicasting, the transmission rate must be set to that of the slowest receiver's rate in order for all subscribers of the multicast to correctly receive the information. With that in mind, if any of the multicast subscribers has a very slow downlink rate, it will result in the entire network's multicasting transmission rate to be equally slow. To get around this problem, the authors of ICAM has devised a method of increasing the throughput via use of using micro WiFi networks within the macro 3G cellular network. In ICAM scheme, In cases where there is a slow receiver within a multicast subscriber, the base station will simply omit the transmission to the slowest receiver. To send the correct information to the omitted subscriber, the base station will designate one of the receivers with the best overall throughput of 3G downlink and WiFi uplink to be a proxy device. This device will simply relay the multicast to the omitted receiver. Through ICAM, the overall network multicasting transmission rate can be increased, hence improving the throughput and minimizing the delay of the 3G network.

1. Introduction

A multicast network is needed in various networks to reach multiple users who are requesting same data. By multicasting, the network in whole can save the resources by not having to retransmit the same data to multiple users in separate instances. This is a great solution in saving resources, but the problem arises as not all users may have the same receiving rate. In the current 3G wireless environment, and as stated in the IEEE publication, *ICAM: Integrated Cellular and Ad Hoc Multicast*[1], the most "conservative" way to solve this problem is to reduce the transmission rate to that of the slowest receiver so that all the receivers including the slowest receiver can correctly receive the transmitted data. This method is shown in Figure 1. As one can imagine, with the increase in number of users, there are greater probability of users with small bandwidth, reducing the throughput of the entire system, which in turn defeats the whole purpose of multicast. To get around this problem, ICAM(Integrated Cellular and Ad Hoc Multicast) can be implemented. ICAM is an Ad Hoc network which uses the available WiFi (IEEE 802.11 network) in tandem with the 3G network. When a multicast transmission is sent, the network will choose a cell with the greatest throughput and use it as a proxy device. When transmitting, instead of matching the transmission rate to that of the slowest user, it will send it at a faster rate by not transmitting to the slowest user at all. Instead, a proxy device will be designated by the network as the device with the fastest overall throughput (both 3G connection and WiFi connection). This proxy device will relay the multicast via IEEE 802.11b network through the internet to the slow users who will also be connected to the IEEE 802.11b network. This process will allow the network to correctly transmit the data to even the slowest receivers without slowing down the entire 3G network transmission rate to match that of the slowest receiver. This multicasting scheme with relay procedure is depicted in Figure 2.

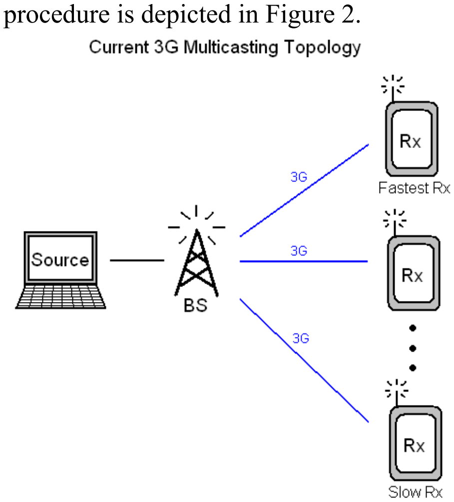

Fig. 1. Current 3G multicasting network (with no relay)

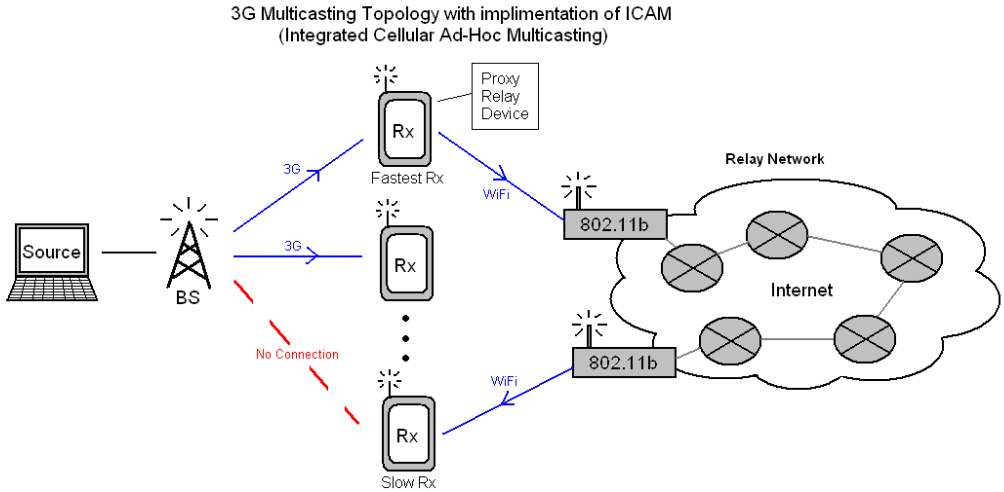

Fig. 2. ICAM 3G multicasting network (with relay)

2. Problem and Approach

ICAM is a method of improving current 3G multicasting protocol by use of WiFi (IEEE 802.11b). The current multicasting protocol in 3G wireless network is set up so that the maximum transmission speed of the base station is set at the slowest receiver's speed in order to correctly transmit the data to all its recipients. One can easily observe how having a large volume of subscribers to a multicast will increase the probability of having a slow receiver within a network, hence greatly reducing everyone else's transmission speed. To reduce the effect of "one slow guy slowing down everyone else", a WiFi relay is made using none other than one of the receivers. In ICAM, the base station will omit transmission to the slow receiver all together, but to correctly send the data to that omitted receiver, a receiver within the multicast network becomes a proxy device which will relay the data via WiFi to the omitted receiver. ICAM does assume the fact that each reciver has simultaneous access to both macro network of a 3G wireless network as well as 802.11b WiFi network as shown in Figure 3.

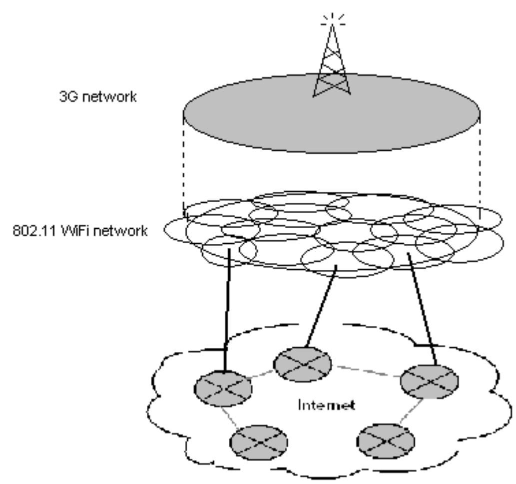

Fig. 3: Overlay of macro 3G wireless network and macro WiFi network.

The goal of this project is to simulate the network using MATLAB and NS2 (Network Simulator 2)[6] to evaluate the throughput of the current 3G multicasting network and that of the proposed ICAM multicasting network.

To simulate both 3G wireless multicasting network and ICAM network, we dissect the problem in three parts. First, we identify the random user's distance from the base station. This procedure is described in section 2.1. With the distance of the furthest user to the base station found, the user's received power and throughput is calculated which are described in section 2.2. Section 2.3 will gather the MATLAB simulation results and compare it to the simulation result of the IEEE published article. Section 2.4 will reevaluate and simulate the scenario using NS2 simulation. The topology, the simulation methods will be shown and the resulting outputs will be presented.

2.1 The Model of Distance of the Furthest Random User (Random Variable)

In a given cell area, we assume that the user is uniformly distributed in a cell area. Assuming we model the cell as a perfect circle, we can say that the number of user is uniformly distributed with respect to angle. We are interested in the distribution of users with respect to radius. We can visualize the circle as being composed of rings with thickness of delta-r as shown in Figure 4. The number of users will be proportional to the area of the rings. As we set the limit of delta-r = 0 the thickness of the rings will become zero and we are left with the circumference of a circle. The circumference of the circle with respect to radius normalized is the distribution function of density of number of users with respect to the radius. This random variable will give us the radius of the circle which represents the distance of a random user from the base station.

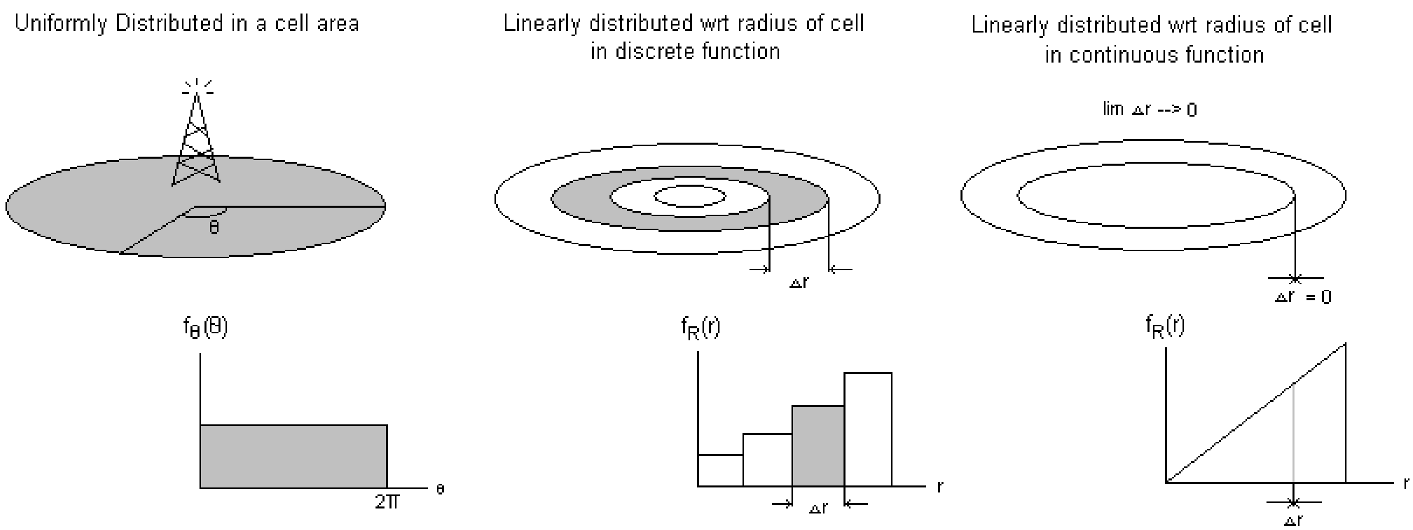

Fig. 4. Distribution of Number of User

This random variable is modeled in MATLAB by transforming a uniform random variable into a linear random variable and is shown in Figure 5.

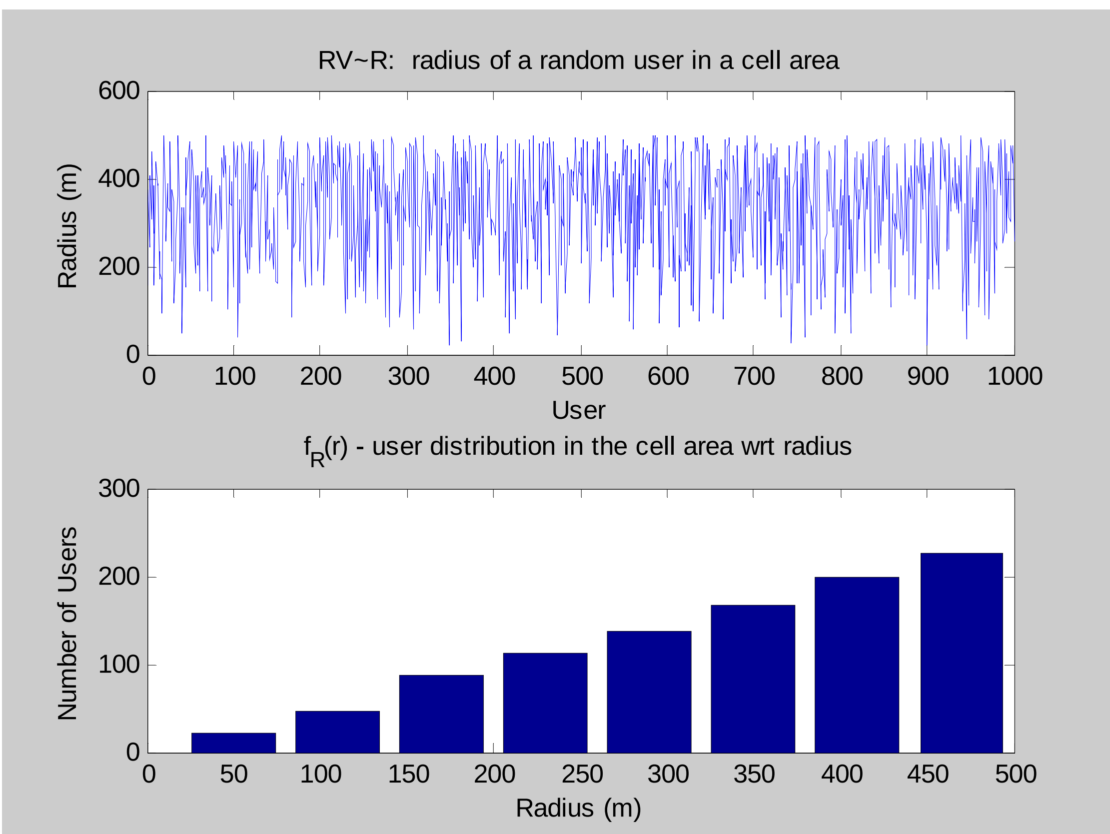

Fig. 5. Linearly distributed random variable representing the distance of a random user in a cell

Now that the random variable of user's distance has been created, we now identify the user who will have the greatest attenuation as that user will most likely have the minimum throughput. The user with the greatest attenuation is modeled as the user who is the furthest from the base station and is calculated as such:

$$\text{Distance of furthest user} = \max\{ d(1), d(2), d(3), \ldots , d(n)\}$$

With d(.) being the distance of user to the base station.

The main difference between the two networks is that for the current 3G multicasting, there is no relay compared to the ICAM multicasting which will drop the slowest receiver and relay its transmission. To model ICAM, we simply drop the user with the greatest distance as that user's data is being relayed and is no longer part of the transmission of the base station. Hence the furthest transmitting distance of ICAM is modeled as the user who has the second greatest distance from the base station. The two cases are shown on Figure 6.

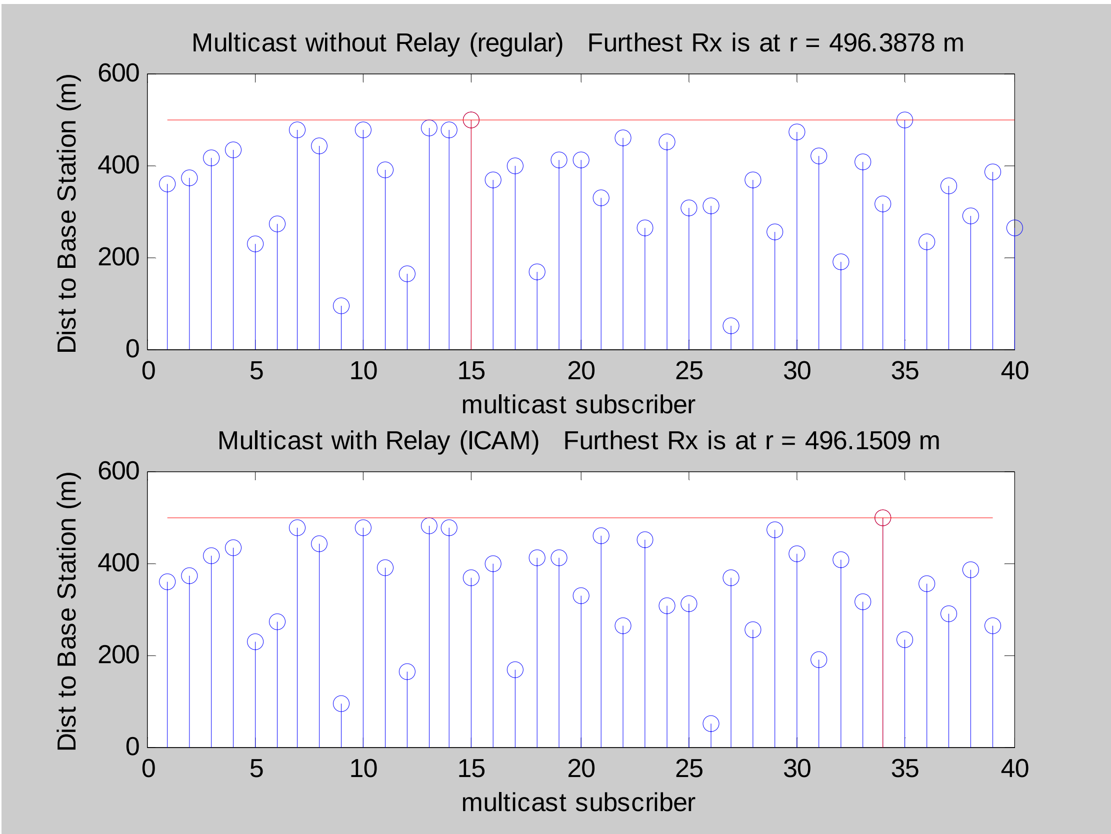

Fig. 6. Distance of random users. (horizontal line represents furthest distance)

We now come up with the average distance of the furthest user by simulating this numerous times and getting the average of that value. We also repeat the process for 5, 10, 20, 30, and 40 users. The simulation results are shown in Figure 7. As expected, as the number of multicast subscribers increase, we see that it is more likely to find a furthest user of a multicast group further away from the base station. Also, note that as we are dropping the furthest receiver for ICAM multicasting, the average distance is significantly less than that of the regular multicasting network for all size of groups.

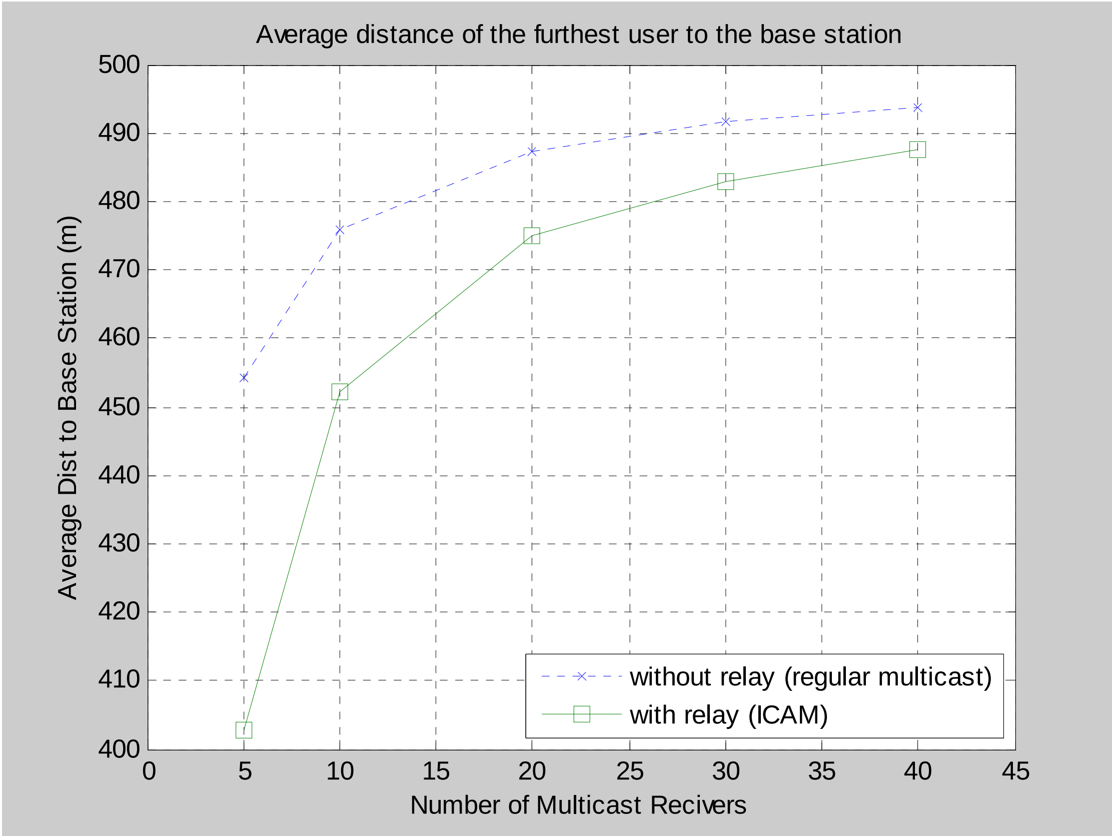

Fig. 7. Average distance of the furthest user of the multicast group

2.2 The Received Power and The Throughput

With the information of the distance of a random user who is furthest from the base station, we can now calculate the power received by each random user. The received power is modeled using the free space model [3]. Other models such as Okumura-Hara Path Loss Model [4] and Lee's Path Model [4] were considered, but were not used due to the fact that it did not conform to ICAM simulation criteria or the limited information given to replicate the simulation. Okumura-Hara path loss model is valid for distance of 1km to 20km which exceeds ICAM simulation parameter of 600m. Lee's path loss model was also not used as it is required to know the power received at distance of 1.6km which was unknown. The free space model [3] shown below was used as it accepts only the limited data that was provided. Figure 8. shows the power received per distance using this model.

$$P_T = P_R G_T G_R (\lambda/4\pi d)^2$$

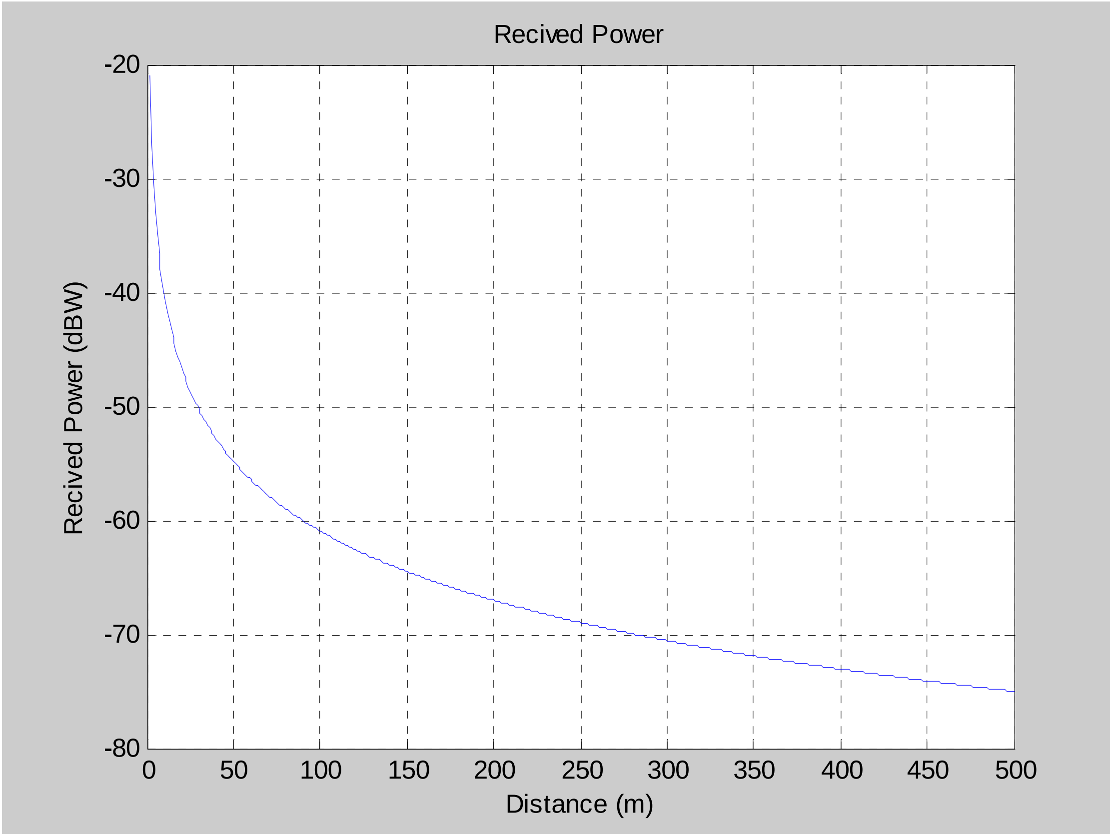

Fig. 8. Received Power at a distance

We now calculate the average power received by the furthest receiver. The results shown in Figure 9.

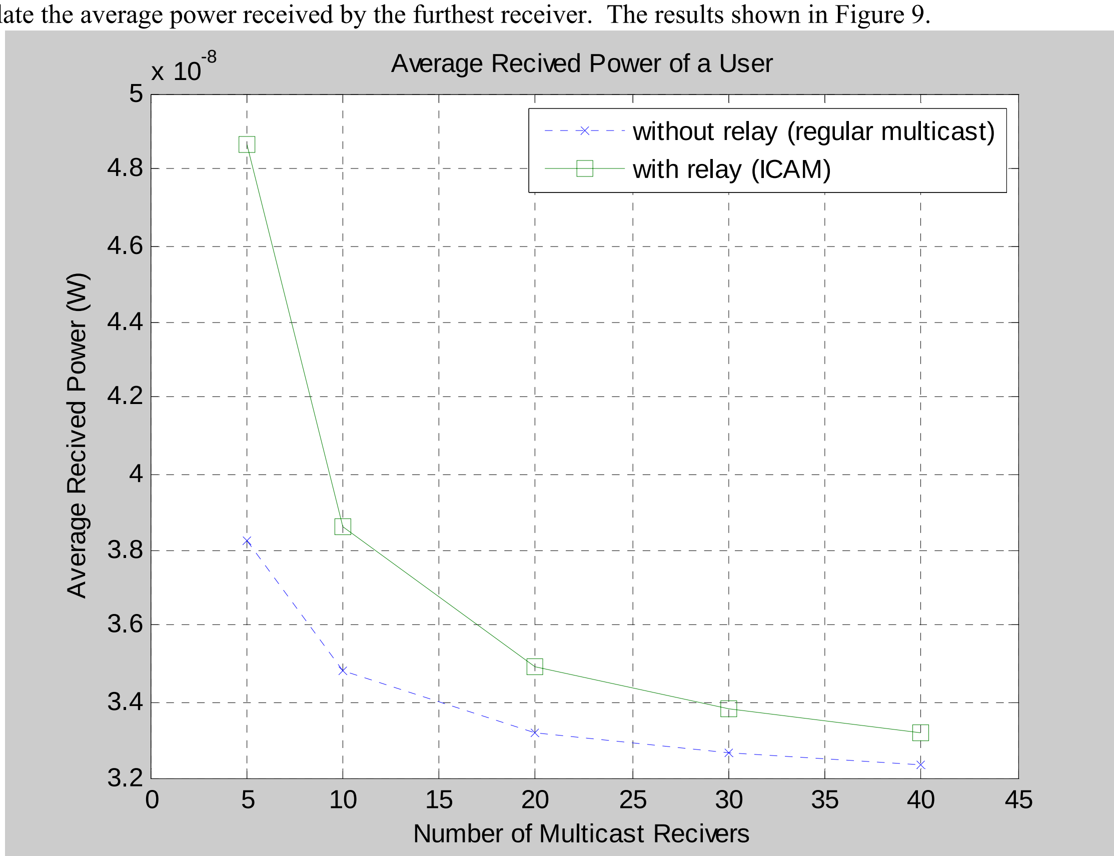

Fig. 9. Average received power of the furthest user of the multicast group

The channel capacity was calculated using the Shannon's Channel Capacity as such:

$$C = BW\log_2(1+P_R/P_n)$$

Where bandwidth was set to 1.25MHz as we are simulating CSMA2000 [5].
Due to the limited simulation criteria provided through the article, the throughput was estimated as the channel capacity.

2.3 Simulation Results

The following are the resulting MATLAB simulation data compared to that of the published IEEE published article.

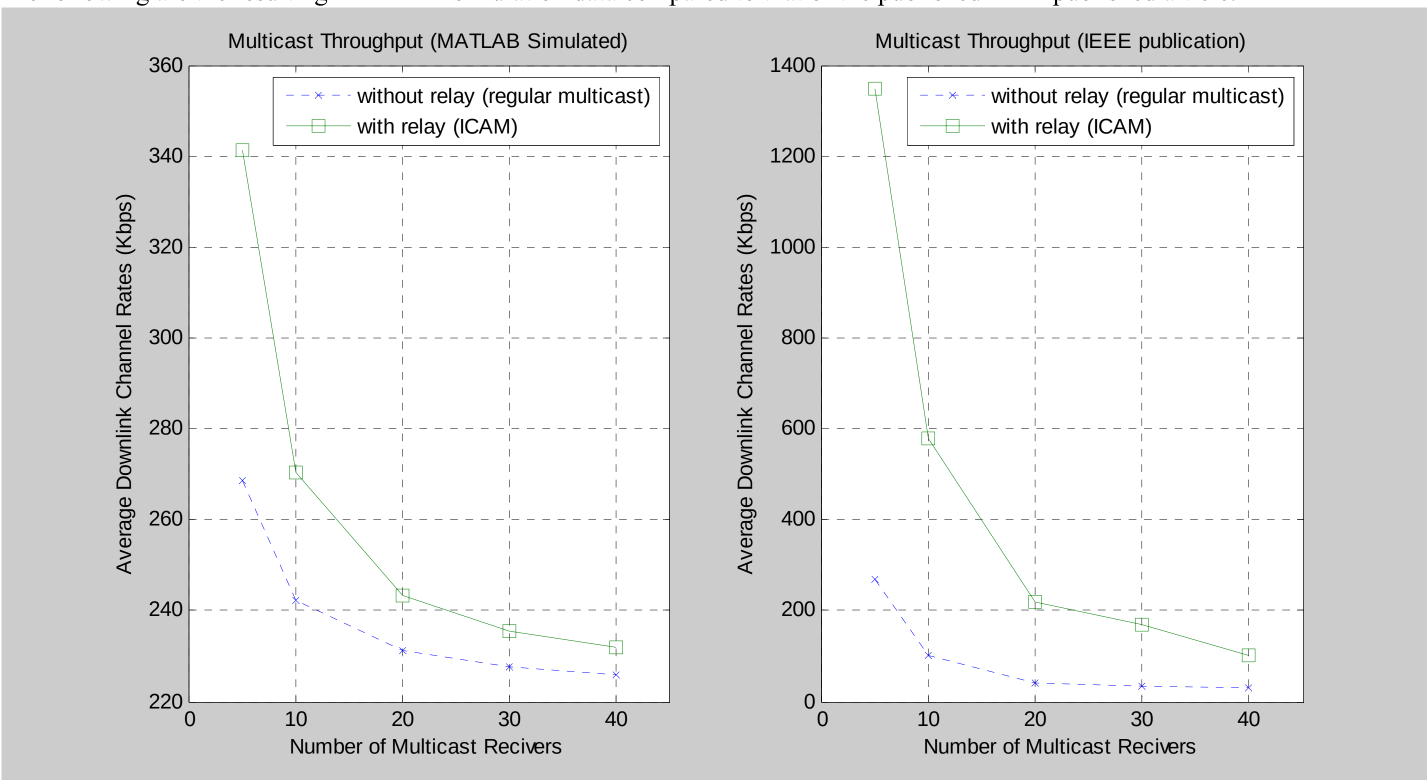

Fig. 10. Average throughput of the multicast network

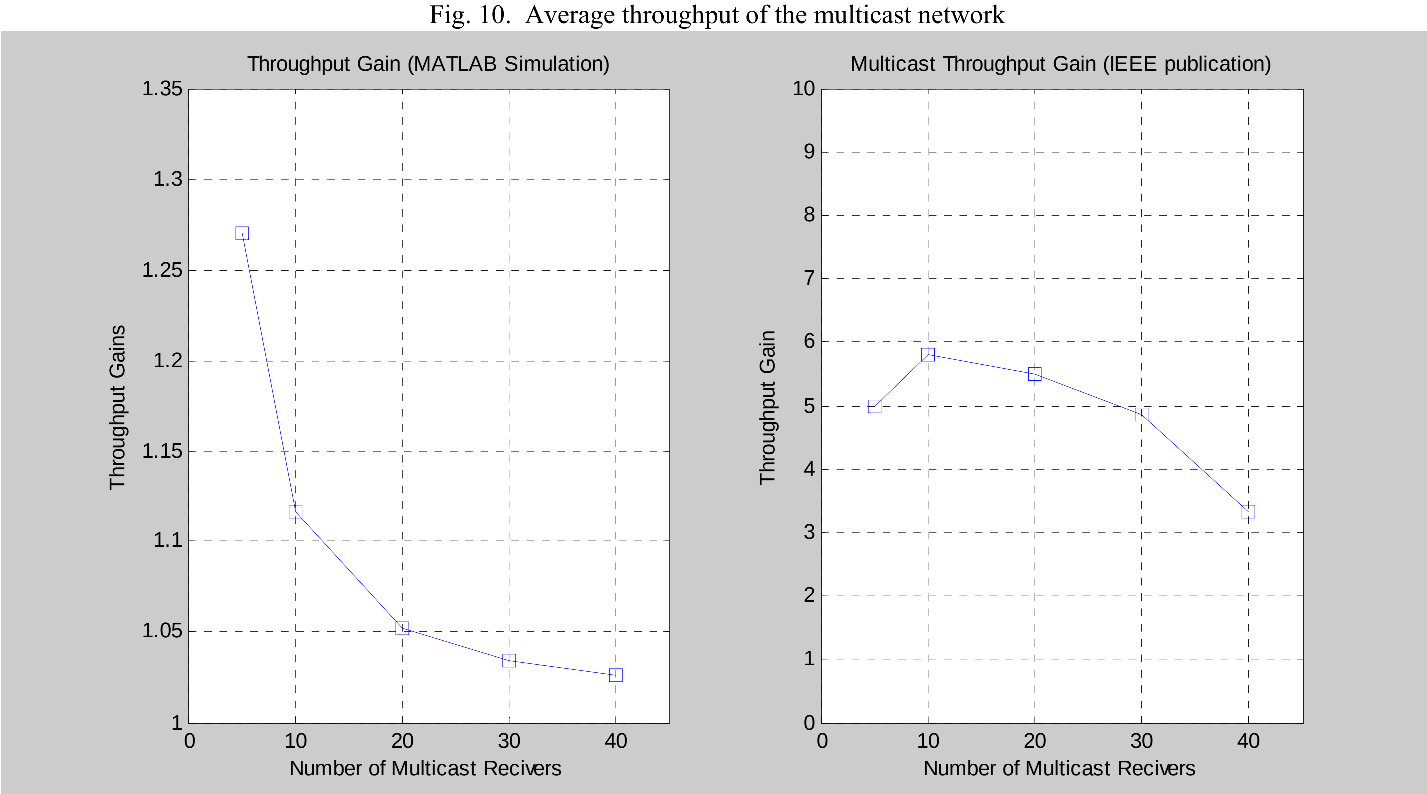

Fig. 11. Average throughput gain of the multicast network

The MATLAB simulation results show that ICAM does indeed increase the network performance, yet comparing this results to the IEEE published ICAM results, the IEEE published results seem ambitious. A possible factor in deviation on the results could have occurred due to the assumptions made due to the lack of information that could be obtained from the published article.

A possible method to increase the gain for ICAM was also studied. If one was to create this system so that it supports more than one relayed receiver at a time, it would greatly improve the overall throughput of the system. Figure 12 shows the throughput for the case if ICAM was able to relay to multiple slow receivers. Figure 13 shows the gain for the corresponding system. Note that the gain for the multicasting group of five for the MATLAB simulation is comparable to that of the IEEE publication with total repeated receiver at four.

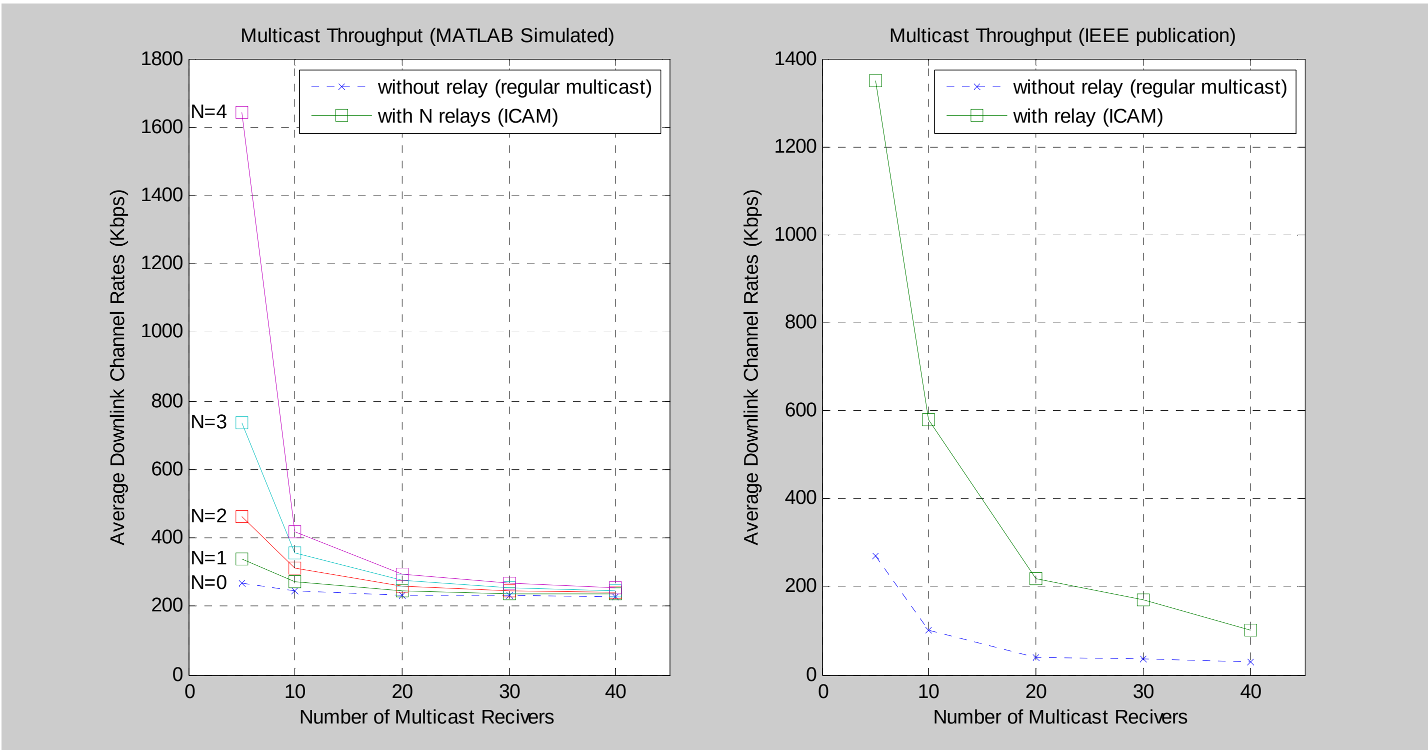

Fig. 12. Throughput for multiple relays.

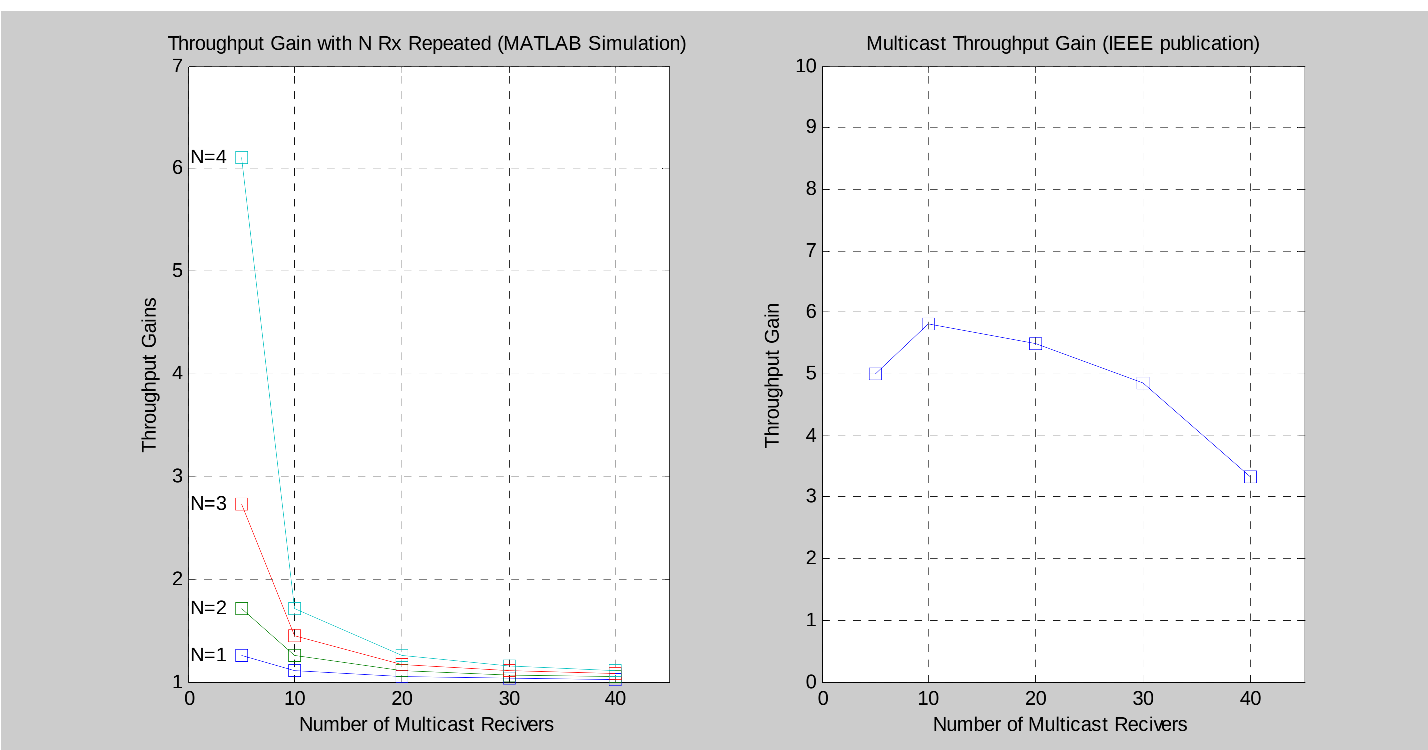

Fig. 13. Gain for multiple relays.

3. Conclusions

As shown through MATLAB simulation results, multicasting through ICAM will greatly improve the overall throughput and the delay of the system. ICAM does assume a fair bit of conditions such as all the users have access to the internet via IEEE 802.11b on top of their 3G cell network. The requirements of ICAM can be a limiting factor in real life implementation, however the knowledge gained from this model can be extended to understanding how using a multiple parallel network in a same geographical region can improve the overall network performance. Also, as the number of micro networks in forms of public WiFi spots are constantly growing in today's metropolitan areas, ICAM multicasting network may have a place in the near future.

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