Load Balanced Clusters for Efficient Mobile Computing

GJCST Computing Classification
C.1.3, C.2.4

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***Abstract*-Mobile computing is distributed computing that involves components with dynamic position during computation. It bestows a new paradigm of mobile ad hoc networks (MANET) for organizing and implementing computation on the fly. MANET is characterized by the flexibility to be deployed and functional in "on-demand" situations, combined with the capability to ship a wide spectrum of applications and buoyancy to dynamically repair around broken links. The underlying issue is routing in such dynamic topology. Numerous studies have shown the difficulty for a routing protocol to scale to large MANET. For this, such network relies on a combination of storing some information about the position of the Mobile Unit (MU) at selected sites and on forming some form of clustering. But the centralized Clusterhead (CH) can become a bottleneck and possibly lead to lower throughput for MANET. We propose a mechanism in which communication outside the cluster is distributed through separate CHs. We prove that the overall averaged throughput increases by using distinct CHs for each neighboring cluster. Although increase in throughput, reduces after one level of traffic rates due to overhead induced by "many" CHs.**

I. MOBILE COMPUTING: VISION AND CHALLENGES

Mobility originates from a desire to move toward the resource or to move away from scarcity and in rare cases it may be just a nomadic move. Wireless mobile computing faces additional constraints induced by wireless communications and the demand for anytime anywhere communication towards the vision of ubiquitous or pervasive computing. It is accepted that the new parameters in mobile computing [1] are mobility of elements, the limited resources of the Mobile Units (MUs) and the limited wireless bandwidth. The "mobility" and "position" has a more significant effect on the development of middleware, simulators and services for the MU than the other parameters. These characteristics can be viewed in a hierarchical fashion where the basic elements influence higher more complicated systems. The mobile computing challenges on the one hand irrevocably handicapped the existing infrastructure in effectively supporting the exponentially rising demands and on the other hand open new avenues and opportunities for Mobile Ad Hoc Network (MANETs). In general, such solutions rely on a combination of storing some information about the position of the MU at selected sites and on forming some form of clustering. The MUs are grouped in distinct or overlapping clusters for the purpose of routing and within the cluster MUs be in touch directly. However, MUs communicate outside the cluster through a centralized MU that is called Clusterhead (CH). CH elected to be part of the backbone for the MANET system and is assigned for communication with all other clusters [2, 3, 4]. This provides a hierarchical MANET system which assists in making the routing scalable. CHs are elected according to several techniques. The CH allows for minimizing routing details overhead from other MU within the cluster. Overlapping clusters might have MUs that are common among them which are called gateways [5]. MANET requires efficient routing algorithm in order to reduce the amount of signaling introduced due to maintaining valid routes, and therefore enhance the overall performance of the MANET system [6,7]. As the CH is the central MU of routing for packets destined outside the cluster in the distinct clustering configuration, the CH computing machine pays a penalty of unfair resource utilization such as battery, CPU, and memory [8]. Several studies [9, 10, 11] have proposed a CH election in order to distribute the load among multiple hosts in the cluster. Our approach extends the same concept of load balancing among CHs too. Section 2 discusses the related work and outlines major challenges while clustering in MANETs, section 3 discusses the multi-CH approach, section 4 presents the system model, section 5 discusses the numerical results obtained, and finally paper is concluded with future scope in section 6.

II. RELATED WORK

Several mechanisms of CH election exist with an objective to endow with efficient mobile computing in terms of stable routing in the MANET system [12, 13]. Some mechanisms favor not changing the CH to reduce the signaling overhead involved in the process, which also makes the elected MU usage of its own resources higher [14]. Other mechanism assigns the CH based on the highest MU ID as in the Linked Cluster Algorithm, LCA [15]. However, this selection process burdens the MU due to its ID. CH can become bottleneck and lead to propagating congestion. One option is to elect CH for a defined duration and then all MUs have a chance to be a CH [3]. This mechanism keeps the CH load within one MU for the CH duration budget, while it provides a balance of responsibilities for MUs within the cluster. Also, MU with a high mobility rate may not get the chance to become a CH if its mobility rate is higher than the duration of CH rotation. But transition and the duration budget contribute greatly to overhead. Mobility is one of the most important challenges of MANETs, and it is the main factor that would change network topology. A good electing

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CH does not move very quickly, because when the clusterhead changes fast, the MUs may be moved out of a cluster and are joined to another existing cluster and thus resulting in reducing the stability of network. Hence, CH election mechanisms consider relative MU mobility to ensure routing path availability [16, 17], however, causing an added signaling overload and causing the elected CH to pay the higher resource utilization penalty. We can conclude from the existing research that several tradeoffs exist for the elected CH and the other cluster MUs. Firstly, the CH has to bear higher resource utilization such as power, which may deplete its battery sooner than other MUs in the cluster. In addition, possibly causing more delay for its own application routing due to the competition with the routing for other MUs. Secondly, despite fair share responsibility of CH role, it is possible that heavy burst of traffic takes place causing some CHs to use maximum resources, while others encounter low traffic bursts resulting in minimum resource use. Thirdly, the fair share or load balancing technique [3], might result in a CH that will not provide the optimal path for routing, or yet a link breakage. Plus non CH are privileged as they don't pay a routing penalty and have resources dedicated for own usage only. Therefore, there is no one common CH election mechanism that is best for MANET systems, without some hurting tradeoffs. The Zone Routing Protocol (ZRP) [18] provides a hybrid approach between proactive routing which produces added routing control messages in the network due to keeping up to date routes, and reactive routing which adds delays due to path discovery and floods the network for route determination. ZRP divides the network into overlapping zones, while clustering can have distinct, non overlapping clusters. In ZRP, Proactive routing is used within the zone, and reactive routing is used outside the zone, instead of using one type of routing for the whole network. In addition, [18, 19] suggest that hybrid approach is suited for large networks, enhances the system efficiency, but adds more complexity. Each MU has a routing zone within a radius of n hops. All MUs with exactly n hops are called peripheral MUs, and the ones with less than n are called interior MUs. This process is repeated for all MUs in the network. A lookup in the MU's routing table helps in deciding if the destination MU is within the zone resulting in proactive routing. Otherwise, the destination is outside the zone, and reactive routing is used which triggers a routing request. As a result of a routing response, one of the peripheral MUs will be used as an exit route from the zone to the destination. While, if clustering is applied, the same elected CH is used for routing outside the cluster without triggering any route discovery to the destination. As discussed above, the main focus of the existing work focuses on an election of single CH for a cluster. Even though this minimizes the overall signaling overhead in the cluster, but it mainly can make the central CH a bottleneck.

A. Challenges And Issues In Clustering

Despite the tremendous potentials and its numerous advantages MANET pose various challenges to research community. This section briefly summarizes some of the major challenges faced while clustering in such network [12-15].

B. Heterogeneous Network

In most cases MANET is heterogeneous consisting of MUs with different energy levels. Some MUs are less energy constrained than others. Usually the fraction of MUs which are less energy constrained is small. In such scenario, the less energy constraint MU are chosen as CH of the cluster and the energy constrained MUs are the member MUs of the cluster. The problem arises in such network when the network is deployed randomly and all cluster heads are concentrated in some particular part of the network resulting in unbalanced cluster formation and also making some portion of the network unreachable. Also if the resulting distribution of the CHs is uniform and if we use multi hop communication, the MUs which are close to the CH are under a heavy load as all the traffic is routed from different areas of the network to the CH is via the neighbors' of the CH. This will cause rapid extinction of the MUs in the neighborhood of the CHs resulting in gaps near the CHs, decreasing of the network size and increasing the network energy consumption. Heterogeneous MANET require careful management of the clusters in order to avoid the problems resulting from unbalanced CH distribution as well as to ensure that the energy consumption across the network is uniform.

C. Network Scalability

In MANET new MUs comes in the vicinity of the current network. The clustering scheme should be able to adapt to changes in the topology of the network. The key point in designing cluster management schemes should be if the algorithm is local and dynamic it will be easy for it to adapt to topology changes.

D. Uniform Energy Consumption

Clustering schemes should ensure that energy dissipation across the network should be balanced and the CH should be rotated in order to balance the network energy consumption.

E. Multihop or Single Hop Communication

The communication model that MANET uses is multi hop. Since energy consumption in wireless systems is directly proportional to the square of the distance, most of the routing algorithms use multi hop communication model since it is more energy efficient in terms of energy consumption however, with multi hop communication the MUs which are closer to the CH are under heavy traffic and can create gaps near the CH when their energy terminates.

F. Cluster Dynamics

Cluster dynamics means how the different parameters of the cluster are determined for example, the number of clusters in a particular network. In some cases the number might be reassigned and in some cases it is dynamic. The CH performs the function of compression as well as

The distance between the CHs is a major issue. It can be dynamic or can be set in accordance with some minimum value. In case of dynamic, there is a possibility of forming unbalanced clusters. While limiting it by some pre-assigned, minimum distance can be effective in some cases but this is an open research issue. Also CH selection can either be centralized or decentralized which both have advantages and disadvantages. The number of clusters might be fixed or dynamic. Fixed number of clusters cause less overhead in that the network will not have to repeatedly go through the set up phase in which clusters are formed. In terms of scalability it is poor.

III. MULTI – CH APPROACH.

The existing clustering approach encourages election of one CH [20, 21]. The proposed work enhanced the architecture to use multiple CHs and distributes the load of the single CH amongst multiple CHs in the same cluster. The proposed mechanism does not mandate a specific CH election process. Any of the prior work [9, 10] can be used to select the CHs for a cluster. By distributing the load, a single CH does not have to bear all the added responsibility of being the central point for routing in a cluster. Therefore, we believe this approach provides a more fair solution of sharing inter-cluster routing responsibilities for a cluster. In addition, other mechanism can be applied to switch the responsibility of a CH to another MU, such as in [3]. In the case of one CH per cluster, a link breakage caused by the failure of the CH isolates all cluster MUs from communicating to/from outside the cluster. However, our approach reduces the link breakage to be only in the direction towards a path where the failed CH forwards the data. Therefore, the reliability of routing in the MANET system is increased. We explore the certain benefits of having multiple sinks in the network as follows:

Energy efficiency: In MANET, long routing path lengths from MU located at the cluster borders to the CH are observed. Adding extra CH to the cluster decreases the average path length between a MU and the CH due to shorter geographic distance between them. Therefore, the number of hops that a packet has to travel to reach a CH gets smaller. Since each traveled hop means the data packet consumes some energy at the visiting MU, traveling fewer hops results in consuming lesser energy.

Avoiding congestion near a CH: Using multiple CHs can also relieve the traffic congestion problem associated with a single-CH system.

Avoiding single point of failure: A single-CH is not robust against failure of the CH or the MU around the CH. Multi-CH are therefore more resilient to MU failures. However, deploying many CHs does not solve the problem directly and evenly. It is essential to distribute cluster load among CHs and choose an optimal route(s) between MU and the corresponding CH. transmission of data.

IV. SYSTEM MODEL

We have used glomosim [22] simulator, running IEEE 802.11 to prove our contribution. Our MANET system consists of four distinct non-overlapping clusters with a physical terrain of 1500 meters by 1500 meters as shown in Fig. 1. For the same cluster, we ran simulation experiments with one CH, and compared its performance results with tests using 3 CHs. Each CH has an independent queue for packets destined for the neighboring clusters for which a particular CH is meant. During the simulation, we maintained the same CHs in both cases (single, multiple CHs), since changing the CH was irrelevant to what we are proving. Our traffic type has Constant Bit Rate, (CBR), and File Transfer Protocol, (FTP), traffic. The same traffic load was run for both cases (single, 3 CHs). The selected traffic load was chosen based on tests that allowed sufficient utilization of the channel.

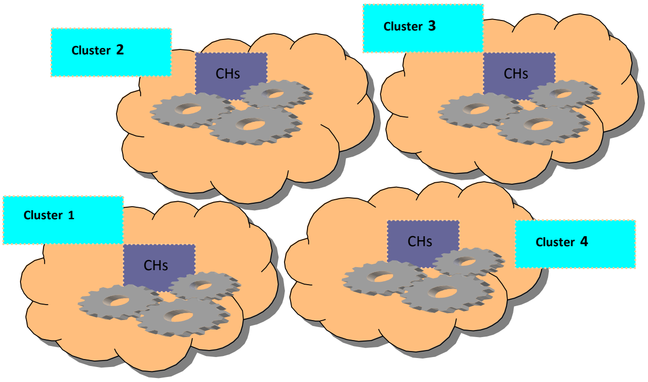

Fig.1. Multi-CH Simulation Setup

In this model Cluster 4 operates as a cluster with one CH and with many CHs. The remaining clusters operate with one CH. This work can be expanded by incrementing the number of CHs in a cluster such that it has one CH per neighboring cluster. Our traffic included FTP traffic generated between MUs in all clusters in the MANET system. The FTP sessions where established in both directions. In addition, CBR traffic was generated in both directions between MUs in cluster 4, and clusters 1, and 2. In order to focus on the objective of distributing the CH load, we setup static routes in our MANET system. Routing from cluster 4 to cluster 2 was done via the intermediate cluster 1/cluster 3, and vice versa. Therefore, since there are 3 neighboring clusters to cluster 4, the system allowed for the use of 3 CHs, one for routing to/from each neighboring cluster.

V. NUMERICAL RESULTS

Our simulation focused on the cumulative averaged throughput and response time. Fig. 2 shows the percentage of increase in throughput when running multiple CHs over using one CH. In all cases, the throughput increased for the multiple CHs case. For the small simulation time of 1000S and with the traffic load used, the increase was only about

18% since the system was lightly loaded as a result of a short simulation time. Therefore, one CH operated well since the channel was not well utilized. Our peak results show that at 7000S of simulation time, we reached a maximum throughput improvement as this case indicates the channel utilization was at its optimal condition. Therefore, for the longer simulation times, beyond what we concluded as optimal, the throughput decreased due to the added traffic on the channel.

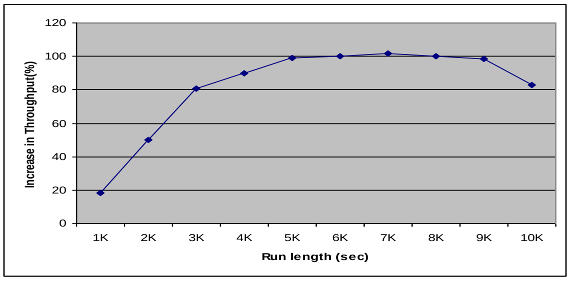

Fig.2. Run length (sec) VS Throughput Improvement (%)

The optimal case of 7000S proves the advantage of distributing the load to multiple CHs, we have gained about 101% improvement in throughput. Our results are explained by the simple queuing theory model:

$$\rho = \lambda / \mu \qquad (1)$$

where, $\boldsymbol{\rho}$ is the traffic intensity, $\boldsymbol{\lambda}$ is the traffic arrival rate and $\boldsymbol{\mu}$ is the service rate at each CH with queue length QLI (*k*,*l*) with *k* as no. of packets and *l* as no. of CHs per cluster. Eq.1 indicates that ρ increases if the λ increases while μ remains at the same rate. In addition, the overall averaged cumulative response time, increases if a constant service rate is maintained, while the traffic arrival rate increases. Our simulation showed that the response time remained constant when using one single CH, and multiple CHs of about 0.5. The traffic rate in the system is given by Box Muller transformation (Eq. 2) with given σ=1 and μ=0 and rand1, rand2 as samples from U (0, 1).

$$s = (-2 \text{ Log } (\text{rand1})^{1/2} \text{ Cos } (2\pi.\ \text{rand2}) \qquad (2)$$

The traffic rate is increased as indicated by the throughput increase due to the multiple CHs, while maintaining the same response time. Normally, if the arrival rate increases while maintaining the same service rate, then the response time should increase accordingly. Therefore, we can conclude that, by maintaining the same response time, the added traffic rate due to an increase in service rate results in constant system utilization. In our topology, we increased the number of CHs to 3. However, our throughput is about doubled as shown in Fig. 2. We should expect by the distribution of work to 3 CHs, and by having the same averaged delay for the MANET system, a 3 fold increase in throughput since the service rate has tripled. However, we only gained double the throughput due to cumulative increase in overall overhead due to the added traffic rate by having multiple queues, one for each CH. In addition, as the traffic arrival rate increased due to having the 3 CHs, the service rate also increased, resulting in the same utilization rate for the MANET system. We ran additional test to validate the traffic rate at our selected simulation time of 7000S. The tests were run with one CH and multiple CHs for cluster 4. The throughput results are presented in Fig. 3. The results show the percentage of increase in the averaged cumulative throughput for running multiple CHs over one CH. We ran test at 4 traffic rates: High, medium (half of the high), low traffic rate (half of the medium) and at much lower traffic rate than the low traffic rate which we called very low rate traffic.

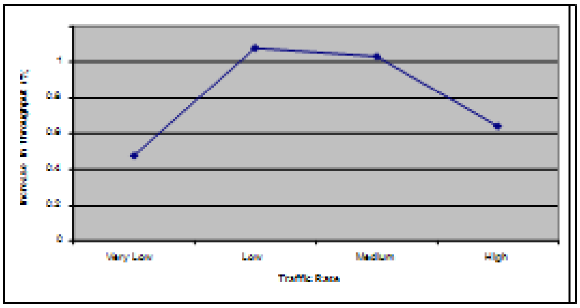

Fig.3. Throughput Improvement (%) VS Traffic Rates

We have noticed, as shown in Fig. 3, the percentage of throughput improvement for the very low was only nearly 50%. This is attributed to the low channel utilization by the low traffic rate. At the high traffic rate we have shown a reduced improvement in throughput due to traffic overload and multi queue overhead in the MANET system. This traffic overload was created by the higher arrival rate due to the added sessions. However, at medium traffic rate, we obtained about the same level of throughput improvement as our optimal selected rate. We conclude that at these rates we obtained system stability with the offered traffic and service rates with many CH. Therefore, the results shown in Fig. 3 validate the selected traffic for our results above

VI. CONCLUSIONS AND FUTURE WORK

Our contribution proves that one CH per cluster does not provide for a maximized throughput of the MANET system due to the added responsibility for the one CH. Using multiple CHs (with independent queue) per cluster distributes the load among multiple MUs which enables simultaneous and shared responsibility of inter cluster routing among multiple MUs. It is an interesting finding to note that the increase in throughput due to the added CHs is proportional to the number of CHs. Beat with the number equal to the neighboring clusters. Depending on the topology and traffic pattern, if all CHs are simultaneously used to route traffic, the rate of throughput increase fails to be the multiplier of the original throughput when using one CH due to overhead of maintaining multiple CHs in a cluster. It is suggested to do further research when having all clusters employing multiple CHs, one per neighboring clusters. Also one expansion of the system model is to take one common queue and dispensing the packet to the idle CH irrespective of the neighboring cluster route. It is expected that the throughput will increase at a very high rate as MANET is blessed with multi hop communication and minimizing the idle time of CHs will lead to balancing the overhead caused by their existence.

VII. REFERENCES

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