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Original Article

A Framework For Scalability On Wireless Connections In Cellular Networks

Edo John[1], Okolie, S.O.[2], Seun Ebiesuwa[3], Charles O. Okunbor[4]

[1,2,3,4] *Babcock University, Department of Computer Science, School of Computing and Engineering Sciences, Ilishan Remo, Ogun State, Nigeria*

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Abstract – *The concept and background of this research are to look at the characteristics of cellular networks amongst the wireless and social layers of complex networks. Then, focus on proximity-driven social models according to which social relations are established with respect to the geographical vicinity of nodes. In this framework, nodes were inclined to communicate with parties that are geographically closer to them more often than with ones at farther distances. When examining the scaling limits, it is often desirable to assume idealistic conditions. While making the problem more tractable, the results of the analysis based on these assumptions reflect the nominal performance of the system. The routing algorithm plays an integral part in the performance of cellular networks. By virtue of this, it is desired to adopt a routing algorithm that exhibits optimal performance.*

Keywords *- Cellular networks, Framework, Routing algorithms, Wireless.*

I. INTRODUCTION

Computer networks can be conceptually organized into several distinct layers that, though logically separate, are operationally interconnected. Within this research, such constructs are often referred to as complex networks. In a complex network, the communication layer represents the physical communication infrastructure, computing servers, and clients. A social layer defines the communication patterns among end-users collaborating with one another through applications running on end systems (host computers). An information layer captures the distribution and relationships among information objects throughout the network. The reciprocal interactions among the communication, social, and information layers of complex networks have an undeniable impact on performance [1]. However, due to the complexity of characterizing complex networks, prior work has focused on the performance of networks from unidimensional viewpoints of communication, social, or information. Examples of studies on communication networks neglecting the latent social relationships are in comparison with several interaction patterns and social paradigms that are independently studied, while the restrictions imposed by realistic underlying communication networks are neglected. Unfortunately, neglecting the interaction among the layers of a complex network renders overly simplified models with implications that are limited in scope and cannot be extended to more sophisticated real-world scenarios [2]. Scalability issues in wireless networks arise due to the networking protocols and application software. The hierarchical and centralized architectures in wireless networks are also responsible for possible lapses. In wireless connections, there are no comprehensive and general approaches to achieving scalability for the high-density network through the decision making of cognitive wireless networking devices. The shortfalls against the scaling throughput in cellular networks, namely bandwidth depletion and inordinate relaying load, are related to the communication layer of the network.

II. LITERATURE REVIEW

A) History of Wireless Network

In February 1896, Guglielmo Marconi journeyed from Italy to England in order to show the British telegraph authorities what he had developed in the way of an operational wireless telegraph apparatus. Through the cooperation of W.H. Peerce, who was at that time the chief electrical engineer of the British Post-office Telegraphs, signals were sent in July 1896 over a distance of one-and-three-fourths miles on Salisbury plain [3].

In 1900, the erection of the first Marconi station at Cape Cod, Massachusetts, began. In March 1901, the Marconi Company installed radio devices at five stations on five islands of the Hawaiian group. For a long time, these installations were to prove to be of little or no value due to the restricted availability scarcity of qualified operatives. During this same year, the Canadian government installed two stations in the Strait of Belle Isle; also constructed where the New York Herald stations at Nantucket, MA, and Nantucket lightship.

Packet Data technology was developed in the mid-1960s and was put into practical application in the ARPANET, which was established in 1969. Since packet radio is most commonly used at higher radio frequencies (VHF), the range of the transmission is somewhat limited. Generally, the transmission range is limited to ‘unobstructed line-of-sight plus approximately 10–15% additional distance. It would not be until the 1980s that the technology needed for such things as pagers and wireless telephones would be perfected to the point that they became widely available consumer products. Although the telephone's use for individual communication largely overshadowed applications for distributing entertainment and news, the reverse would be true for radio, with broadcasting dominating for decades, before radio transmissions would be significantly developed for personal, mobile communication[3]. This brings us to our present-day cellular networks, where there are radio ports with antennas that connect to base stations (BSs) that serve the user equipment known as mobile stations (MSs). The communication that takes place from the MS to the BS is known as the uplink, while the communication from the BS to the MS is known as the downlink.

B) Wireless Network Architecture and Design

A wireless network consists of several components that support communication using radio or light waves propagating through an air medium. Some of these elements overlap with those of wired networks, but special consideration is necessary for all these components when deploying a wireless network.

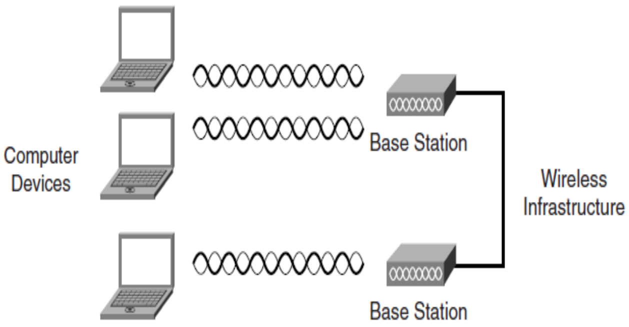

Fig.1 A simple Wireless Network Infrastructure.

A user can be anything that directly utilizes the wireless network. One of the most common types of users is a person. For example, a business traveller accessing the internet from a public wireless LAN at an airport is a user. The user initiates and terminates the use of a wireless network, making the term end-user appropriate.

Typically, a user operates a computer device that often performs a variety of application-specific functions in addition to offering an interface to the wireless network[4].

Users of wireless networks tend to be mobile, constantly moving throughout a facility, campus or city. Mobility is one of the prominent benefits of deploying a wireless network. Some users might require only portability, whereby they stay at a particular location while using the wireless network for a specific period of time. Other users might actually be stationary, which means that they operate from one place for an indefinite period of time[4].

C) Characterization of Physical Wireless Connection

Physical wireless connections are characterized into wireless middleware, data bundling and end support system, which comprises web surfing and email that performs over wireless networks. All it takes is a browser and email software on the client device. Users might lose a wireless connection from time to time, but the protocols in use for these relatively simple applications are resilient under most conditions.

a) ***Wireless Middleware***

This software provides intermediate communication between the user's computer devices and the application software or database located on a server. The middleware, which runs on a dedicated computer (middle gateway) attached to the wired network, will process the packets that pass between the user computing devices and the servers.

b) ***Data Bundling***

Some middleware is capable of combing smaller data packets into a single large packet for transmission over the wireless network, which can help lower transmission service costs of WANs. Since some wireless data services charge users by the packet, data bundling results in a lower aggregate cost.

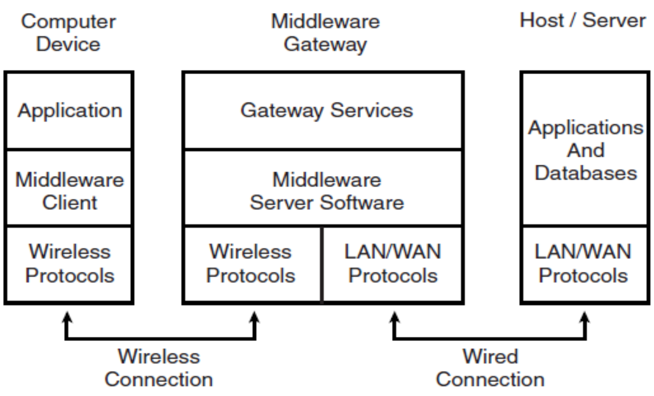

Fig. 2 Wireless Middle interconnects Device application to Hosts and Servers

c) End System Support

Wireless middleware interfaces with a variety of end-system applications and databases. If the clients need access to multiple types of applications and databases, wireless middleware acts as a connector.

D. Models for Achieving Scalability in Systems

The term scalable is often used to describe systems capable of handling a large number of users without incurring a significant loss in performance. In this section, a more objective definition of scalability will be presented. A cost metric that reflects the average amount of resources is needed to accommodate a typical user. In the context of communication networks, a reasonable cost measure is the average number of times a packet needs to be transmitted until delivery to its intended destination. There are three key factors that influence this measure, namely,

- Topological factors, such as the physical connectivity among nodes and the number of hops separating a source-destination pair on the communication graph;

- Social factors, such as the governing patterns according to which nodes interact with one another, and how a source node chooses its destinations; and
- Unrestrained factors related to the physical layer effects or network load dynamics in general; factors such as interference, fading, noise and congestion might result in loss of packets and incur re-transmissions. In this section, the focus is on topological and social factors, which can be modelled under a minimal and general set of assumptions discussed in the following subsections [6].

a) *The Connectivity Graph Model*

For the underlying network topology, let us consider a Random Geometric Graph$\{RGG\}$. Thanks to their simplicity and generality,$[RGG]$'s has become a defector standard in the research community to represent the underlying topology of wireless networks. A definition of RGG is provided in the following for future reference.

Definition 1:$G(X;r)$Represents a random geometric graph in which X is a point process on $(R)^k$ That describes the distribution of nodes. Further, an undirected edge connects every pair $u$and v $iff \|X_U - X_V\| \leq$ r for a given $r \in$ Ɽ+.

For simplicity, we assume that nodes are distributed on the surface of a sphere. This assumption has been commonly used to alleviate the network edge effect. It has been shown that similar results can be derived when nodes are distributed on the plane though through much more tedious and unwieldy computations. Two distinct models are usually considered when studying asymptotic behaviours of RGG's: the extended model, in which the node density is fixed but the network dimensions go to infinity, and the dense model, in which the network dimensions are fixed but the node density goes to infinity.

b) *The Social Model Proximity*

The social model describes the quality and frequency of inter-node communications in the network, i.e., how sources choose their destinations. In this section, we consider a proximity-driven social model defined as follows.

Definition 2: A communication network follows a proximity-driven social model if the probability of every node u and v communicating with each other is inversely proportional to $\|X_u - X_v\|^{\alpha}$for some arbitrary but fixed exponent α ∈$Ɽ_0^+$

Definition 2 implies a social model that is power-law distributed with distance. For a specific realization of the network, the probability of node u choosing as a destination, P_u is obtained as follows:

$$P_u(v) = \frac{d(u,v^{-\alpha})}{\sum_{w \neq u} d(u,w)^{-\alpha}} \quad (1)$$

Where$d\{u,v\}$ =$\|X_u - X_v\|$ The denominator of (1) is, in fact, a normalizing constant (for that specific realization**).** **Source:** (Massimo, 2017)

According to Eq. (1), the closer two nodes are geographical, the more likely they are to communicate; except for the case of α = 0 that results in a uniform communication model in which a source node is equally likely to choose any other node as its destination, irrespective of their distance. Let us denote the number of nodes in the network by n. We want to obtain a probability distribution for the event of having social contact at any given physical distance. For the sake of generality, we normalize the distance metric with respect to the critical transmission range r(n).

E. *Limitation to Scalability in Wireless Networks*

The scalability of computer communication networks has been an important topic for quite some time. Internet community examined the services and protocols for scalability, switching and routing researchers looked at the scalability of the switches and routers. Service providers have used architectures of the services for the scalable performance that they need to provide to subscribers and the maintenance of service provisioning algorithms, protocols and software. Similarly, the wireless networking community has also started to look at the scalability issues that are relevant to wireless cellular, wireless local as well as wireless personal area networks such as ad-hoc and sensor networks. A wireless sensor network is likely to have a large number of nodes, perhaps in thousands to millions, and that may create potentially numerous scaling problems in the networking protocols, addressing schemes, hardware architecture [7]

Several approximations of optimal routings, such as routing along the straight line and grid-based routing. These approximations are often sufficiently accurate when studying a random dense network but are less useful for the analysis of extended networks with finite density. Moreover, the internal mechanisms of such routing schemes are remarkably different from how distributed routing algorithms work in real networks.

Despite the theoretical difficulties in the analysis of optimal routing in random configurations, more tractable solutions with near-optimal performance can still be conceived. One such routing strategy is known as greedy (geographical) forwarding, in which intermediate relays attempt to push the packet some distance closer to the destination. With this policy, even though the global structure of the routes need not be necessarily optimized, a sub-optimal path can still be found by making locally optimized decisions when choosing subsequent relays along the path.

Secondly, to emphasize workable solutions, the huge workloads and difficulties of network configuration are afflicting administrators in operational networks today. As such, real-world deployment (or deployability at the least) must be considered. The key measure of success. Therefore, even though we propose new network "architectures", we always consider prototyping and testing with real-world traffic as integral parts of design and evaluation. By the same token, we sometimes deliberately move away from architecturally pure or clean-slate approaches, and we instead embrace substituting backwards compatible techniques if doing so ensures more practicality [8].

Meanwhile, this emphasis on workable solutions also leads us to a more specific goal of this dissertation. That is because self-configuration alone is not sufficiently practical for real-world deployment. For example, Ethernet bridging supports plug-and-play networking by allowing hosts to communicate with each other using their own unique and permanent identifiers – Media Access Control addresses (MAC) – regardless of their locations in a network, and by letting a network self-learn hosts' address and location information. This mechanism, though effective in eliminating host-address configuration (i.e., assigning location-dependent identifiers to hosts) and routing configuration (i.e., informing routers/switches of hosts' identifiers and locations), does not permit the network to grow beyond a small-scale deployment. This limitation arises from the fact that the self-learning capability relies on frequent network-wide dissemination of individual hosts' information, known as broadcasting and flooding.

a. Review of Related Works

Brent, in [8], proposed a scalability study of enterprise network architecture; Enterprise networks are composed of Ethernet subnets interconnected by IP routers. These routers require expensive configuration and maintenance. If the Ethernet subnets are made more scalable, the high cost of the IP routers can be eliminated. Unfortunately, it has been widely acknowledged that Ethernet does not scale well because it relies on broadcast, which wastes bandwidth, and a cycle-free topology, which poorly distributes load and forwarding state. The gap identified is that the system relying on broadcasts prevents scalability by wasting bandwidth and forcing the active forwarding topology to be cycle-free.

Changhoonin [9] proposed a scalable and efficient self-configuring network; at the centre of the enormous difficulty of configurations, he used a Sisyphean task of updating the operational settings of numerous network devices and protocols. Much has been done to mask this configuration complexity intrinsic to conventional networks, but little effort has been made to redesign the networks themselves to make them easier to configure.

Amin, Ghankun, Williams, Zhou, and Chang in [10], proposed scalability and accuracy in a large-scale network emulator by using ModelNet, a scalable Internet emulation environment that enables researchers to deploy unmodified software prototypes in a configurable Internet-like environment and subject them to faults and varying network conditions. The gap identified to evaluate the system and test the system must be deployed in a real-world scenario, but the results are not reproducible or predictive of future behaviours because the wide-area network is not subject to the researcher's control over the target platform.

Suli, in [11], proposed a scalability and performance evaluation of hierarchical hybrid wireless networks for the problem of scaling ad hoc wireless networks now being applied to urban mesh and sensor network scenarios. Previous results have shown that the inherent scaling problems of a multi-hop "flat" ad hoc wireless network can be improved by a "hybrid network" with an appropriate proportion of radio nodes with wired network connections. The gap identified is that ad hoc demands ad hoc on-demand distance vector (AODV) suffer from decreasing throughput per node as node density increases.

Jacobson proposed bottleneck bandwidth and roundtrip for the network path, and traffic travelling over it can make sudden dramatic changes in network scalability [12]. To adapt to these smoothly and robustly and reduce packet losses in such cases, Bottleneck Bandwidth Round-tip (BBR) uses a number of strategies to implement the core model. The gap identified is when bottleneck buffers are small, loss-based system control misinterprets loss as a signal of low scaling performance, leading to low throughput.

III. METHODOLOGY

Wireless connections are driving the creation of huge data centres, holding tens to thousands of servers that support a large number of distinct services (web apps, emails, and map-reduce clusters). These wireless connection data centres depend on scalability that covers reliability and performance to achieve thorough large pools of inexpensive resources that can be reassigned between services when needed. Data centre network is not up to the task falling short in several ways; first, the existing framework in the literature does not provide enough capacity between the servers they interconnect. Conventional architectures rely on tree-like network configurations built from high-cost hardware. This limits communication between the servers and their wireless connectivity that points out fragments in the server pool.

Secondly, data centres host multiple services; the wireless network does little to prevent a traffic flood in one service from affecting the other services around it. When one service experience a traffic flood, it is common for all those sharing the same network subtree to suffer collateral damage. The design of a wireless connection that achieves scalability by assigning topologically significant IP addresses and dividing servers among VLANs is a routing design that exists in conventional wireless connections. However, this creates an enormous configuration burden when servers must be reassigned among services which further fragments the resources of the data centre and the human involvement typically required in these reconfigurations, which limits the speed of the process.

Cellular network service application owners do not want to be forced to alter their services to work around the structure or limitations of scalability in data centre networks as they frequently are doing today. Rather they work with a mental model that all the servers currently assigned to their service are only those servers that are connected by a single non-blocking Ethernet switch- a virtual Layer 2. In order to achieve scalability for the wireless connections, the following needs to be in place firstly, the wireless connection should provide uniform capacity between all servers meaning the maximum rate of flow should be limited only by the available capacity on the network interface cards of the sending and receiving servers, and there is no need to consider network topology when adding servers to service. Second, the data centre needs performance isolation which means that the traffic of one service should be unaffected by the traffic handled by another service, just as if each service was connected by a separate physical switch. Third, the network should provide layer-2 semantics, just as if the servers were on a LAN because LANS have flat addressing where any IP address can be connected to any port of an Ethernet switch.

The assumption that a network in which all nodes use the IEEE 802.11 MAC protocol with distributed coordination function (DCF). A static discovery procedure pre-computer is well balanced in a hierarchical network topology. Then consider different routing protocols like the ad hoc routing protocols, including DSR, AODV and destination sequence distance vector (DSDV), which are modified appropriately for use in the hierarchical network.

a. Scalability Framework Evaluation

The reason for exploring the three factors for this research is to propose solutions where there are issues, and for this reason, these areas are generalized on which solutions are built. We know that wireless connections are broad, and over the years, to proffer solutions to the issues raised has been in progress by researchers. We briefly introduce each of these factors and their evaluations and give their results.

The overheads of the wireless mediums and the routing control system can be quite large and tend to originate the tendency to degrade system performance. Hence, we investigate the system performance and scaling properties of the three-tier of scalability that exists in the network system. It is of interest to consider the analysis obtained from scaling relationships that hold system simulations with realistic protocols and traffic assumptions. This does not mean that regular topologies cannot be used for wireless connections. Cellular networks can provide high bisection bandwidth and path redundancy which can improve performance and fault tolerance while reducing cost. However, a network topology should not be required for correct operation when misconfiguration and geographical constraints are possible.

Wireless networks are widely used to connect our computers to the internet; thus, it is important to verify wireless network applications. However, reproducing wireless network environments are sensitive to various environmental conditions. Many wireless networks emulators, simulators and technologies for reproducing wireless networks have been proposed over time. So, to evaluate how wireless networks are influenced by the scalability approach is largely outlined in the table below according to the order of high preference, each stating target, motivation, deployment, result, and approach.\

Table 1. Feasibility study of scalability framework

	Topological constraints	Social constraints	Unrestrained constraints
Target	Wireless connections	Cellular networks	Service-provider networks
Motivation	Self-configuration is needed; there is a huge dependency because of the network management, which is limited in the networks.	Self-configuration improves scalability and agility (i.e.) ability to reassign any resource to a data centre of a cloud computing data centre	Service providers are in need of memory storage capacity to blend with fast-growing numbers and size of consumers in cellular networks
Deployment	Several prototypes have been built by research developers.	It is to be used for a large public computing cloud infrastructure	Pre-deployment of passed system tests are expected to be deployed to large consumers
Result	It combines internet protocol (IP) scalability low overhead to maintain host state and efficiency with its self-configuration	It offers the full switch of layer-2, thereby causing non-blocking capacity between servers and agility	Reduce router's memory footprint required for storing customer's information without harming end-to-end performance
Approach	A fresh start on networks.	A fresh start on hosts	Backwards compatible

A) Principles and Applications

In this research work, the feasibility study shows the three areas where scalability is summarized and how it concerns those key areas, for designing scalable and efficient self-configuring networks, the need to summarize the key principles which are utilized in each of the architectures introduced in this research work.

Table 2. Principles and Application

Applications	Flat addressing	Traffic indirection	Usage-based optimization
Wireless connection	MAC-address-based routing	Forwarding traffic through resolver switches	Caching host info at ingress switches and reactive cache update
Cellular network	Separating hosts names from their locations	Forwarding traffic through randomly chosen indirect paths	Utilizing ARP, and reactive cache update
Service provider	Location-independent site addressing	Forwarding traffic through hub routers	Popularity-driven hub selection

B) Discussion of findings

The large memory footprint of wireless communication is an impending critical problem in cellular service providers. As a solution, the suggestion of relaying the scalability routing framework is proposed. Relaying enables routers to reduce tables significantly by offering indirect any-to-any reachability among cellular networks. Despite the benefit, there are two practical applications that must be considered. First, from customer sites point of view, end-to-end communication latency over a VPN should not increase noticeably. Second, for the service provider's sake, relaying should not significantly increase the workload on the backbone.

Reflecting these requirements, the evaluation of the principles to solve the problem of routing configuration and topologies draw the following findings

- When one can allow the path lengths of common conversations to increase by a few hundred miles (i.e. a few msec in unidirectional latency) at most, relaying can reduce memory consumption by 80 to 90%.
- Enforcing the additional distance limit to every conversation rather than only common ones, relaying can still save a percentage of memory of about 60 to 80% and unidirectional latency of 10msec.
- An increase in memory saving is to tightly bound the increase of workload on the backbone and bound additional latency of individual conversations.

The space of alternatives increases if we hold to this strict backwards compatibility assumption. One interesting possibility involves combining caching with relaying, where relaying is used as a resolution scheme to handle cache misses. Another revolves around having hubs keep smaller non-overlapping portions of the address space rather than the entire space and utilizing advanced resolution mechanisms.

IV. CONCLUSION

In emerging operational networks, the need for self-configuring network architectures. To run emerging applications, such as cloud or utility computing, a self-configuring network is also paramount because such a network can substantially reduce service-management workload and increase resource utilization. For real-world deployment, however, self-configuration must be scalable and efficient all at once. As part of a larger effort to redesign networks with this goal in mind, this dissertation focuses on scalability and proposes a highly scalable network architecture that combines Ethernet's and IP's efficiency. The comprehensive approach in this dissertation is that we do not claim completeness. In other words, there is a recognition that cellular networks have a wide range of things that are worked on daily, and this means that was is achieved is compared to what has already been in place to ensure that the framework which is proposed will benefit the development of appropriate architectures for existing wireless technologies.

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