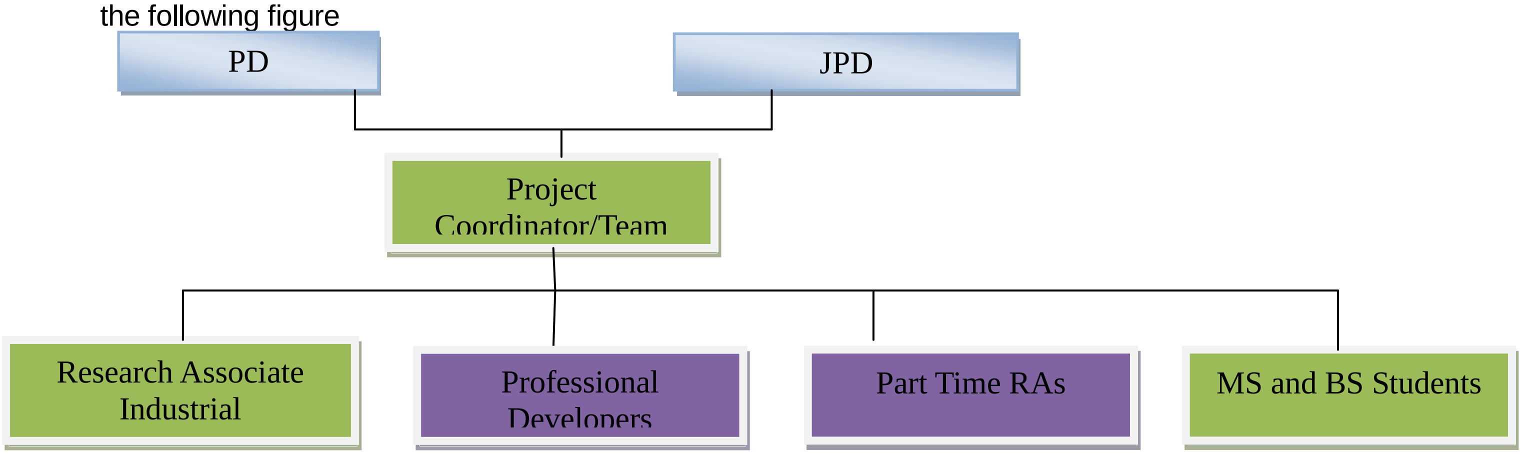
1. Hiring Report:

Most of the team has been hired. We submitted a change request to ICT R&D which was duly approved where we requested for the provision of using the salary of one professional developer for the salary of two part time RAs. The proposed team structure has been changed and shown in the following figure



The following people have been hired on the project

1. Team Lead
2. Research Associate Industrial
3. One Professional Developer
4. One part time RA
5. MS Student
6. BS Student

We conducted interviews of several people before deciding the eventual team members. The research associate industrial has been part of the team since the time of submission. We still need to hire one more professional developer and one part time RA as well we are searching for the appropriate candidate. Furthermore, we are in the process of placing order for most of the equipment and the rest of the equipment would also be ordered very soon.

Task Assignment Report:

The team lead assigns task to professional developers and research assistants. Currently most of the tasks have been related to literature review. Now we move to more technical task like incorporating mobility management in the open source protocol stack. Furthermore, we have also started working on android app development which would be required in one of the future deliverables.

Literature Review

Using mobile station as a device to collect location information has been a part of many implementations as it will actually predict the network coverage performance conditions. To date wireless mobile communications network operators have utilized either the spatial or temporal user information for resource allocation. Optimal resource allocation based on the location of mobile user has been addressed by a few.

Key concepts to the urban planning community using location based service (LBS) involves continuous tracing of mobile phones to collect information about their location with respect to time [1]. Individual users have also been traced through the network using paging. However, tracing techniques lead to an increased payload at the network monitor.

A spatial traffic estimation model that took into account the geographical and demographical factors for the expected tele-traffic in a service region is defined by using a demand based and integrated mobile network planning approach [2].

The possibilities of adopting probing techniques, Observed Time Difference Of Arrival (OTDOA) and Data Correlation Method (DCM) for planning and monitoring of UMTS networks in urban environments, based on the location information are discussed in [4]. An adaptive handoff algorithm based on dynamically determining the handoff threshold value as a function of the MS location, difference in signal strengths and measured RF propagation statistics is presented in [5] with an improvement over previous algorithms that it dynamically changes according to the MS location. In a similar context, efficient location based and optimized hard handoff algorithms were studied in [6-8]. Database management systems for the spatio-temporal models are presented in [20], before which the research in spatial and temporal database models was done independently.

Location management methods for 3G mobile systems are studied in [21]. Data sets of up to 40,000 points per person were generated using GPS for several individuals in the year 2000 with further collection exercises planned [28]. The user trends are derived and the spatiotemporal data sets are analyzed using real-world cell phone log data [30]. A linear time variant community model (TVC) for wireless mobile networks is proposed in [31] which preserves common mobility characteristics and can also be used to derive average node degree, hitting time and the meeting time.

Issues related to mobile user similarity, its definition, analysis and modeling are discussed in [32]. A statistical approach to estimate a person's space-time path is proposed in [33]. A method and apparatus for designing a communication system where user call demand is estimated based on the spatial and temporal distributions [9]. In another patent [10], the authors combined the collected data from the switch at a Mobile Telephone Switching Office with location information of a mobile unit to generate information reports concerning the electromagnetic coverage of geographic region. Geographic location information from mobile stations is analyzed and the areas of good RF converge and poor RF coverage are identified by obtaining RSSI and geographical location information within the mobile device [11-12]. The refinement by mobile is to find the weak signal area in limited range of area of mobile.

The programs installed on mobile station are remotely changed/ installed through wireless medium [13-14] and are used for improved monitoring, measurement and analysis of communication networks utilizing dynamically and remotely configurable probes [15]. A Performance, Optimization and Forecasting Tool (POF) is proposed in [16], to help an evolving network operator who wishes to have a network running at lower cost, offering a competitive Quality of Service (QoS) to its subscribers.

Cellular network optimization based on mobile Location (CELLO), [3], had the objectives to develop Mobile Network Geographic Information System (MGIS) for collecting and maintaining location-based performance data from the mobile network. Moreover it developed Adaptive Coverage System (ACS) for intelligent capacity allocation, a new network planning, optimization and monitoring method based on the MGIS data. This project was based on elaborating the ideas of [17], [18], and [19]. Mobile location in [3] was obtained using Helsinki trial location method developed by Elisa Communications, based on RSSI, however timing advance information is used in some cases to improve the solution.

The Hypergeo (www.hypergeo.eu) project aimed to develop a prototype tourist information service for the delivery of timely location information taking into account information technologies, geographic information and communication infrastructures. The system is made location aware using GPS. The primary contribution of the GIS to the Hypergeo project is to develop components to manage the geo-location of users [29]. The first element of this is to develop a geo-location device then transmit and store this individual spatio-temporal data in a logical way. The second element is analysis of the position history looking for trends and summarizing the data using novel algorithms to extract location trends of individual users, along with the tool for visual analysis of spatio-temporal data.

Self Organizing Networks (SON) is another concept for Next Generation Mobile Networks introduced in Release 8 of 3GPP [44] which automates fault detection and compensation in mobile networks. Several studies have been conducted in this area, Reference [45] uses machine learning techniques to automate troubleshooting tasks by first developing a fault model using KPI alarms generated at base stations and then using NN classifier technique to detecting unknown faults in UMTS network. Another study [46] uses Bayesian networks for diagnosis by calculating the probability of list of causes for each cell using alarms etc. and thus improving overall operational efficiency of the network.

Minimization of Drive Tests (MDT) is another technique introduced and specified in 3GPP Release 9 [47] for automation of data measurements and configurations in UMTS and LTE by using each device which is registered on the network so this approach should provide measurement data for fault detection and optimization in all possible locations covered by the network. Reference [48] has demonstrated the difference between drive tests and MDT and compared their performance on use cases such as MDT can reduce operational efforts and increase network quality and performance, but this approach can’t be implemented in the rollout phase of new technologies where only drive testing works. Another challenge this technique faces is the indoor location measurements.

Reference [49] has created a framework for detection of sleeping cells in LTE network under the umbrella of COD (Cell Outage Detection) and COC (Cell Outage Compensation) in SON. They used MDT functionality implemented in Release 10 of 3GPP to create datasets and then employ machine learning techniques to first learn the network profile and then use anomaly detection techniques to detect cells in outage. Fuzzy logic based approaches are then proposed for automatic compensation of sleeping cells by changing the antenna transmit power and beam width.

Differences from the existing literature:

In this project, we would be working on two dimensional (2-D) spatio-temporal user density modeling. The basic purpose of this project is to unite the concepts of autonomous element and spatio-temporal user density models to enable the users to view their network quality and participate in the network planning and efficient resource allocation. The concepts demonstrated in [10],[11],[12],[13],[14] and [15] will be used. Once we have a user density model with the spatio-temporal knowledge, efficient network planning, monitoring and resource allocation can then be carried out. This project deals with the development of a cost effective solution comprising a set of SW applications running on different location aware mobile handsets using different mobile operating systems and another one running on a centralized RF coverage optimization server collecting all of that data and performing authentication, data validation, data analysis functions and creating necessary reports and determining the state of key performance indices and recommending actions. We intend to indigenously, if any, that might be necessary without having any dependence on the existing network operator infrastructure thus being termed as autonomous network management and RF coverage optimization.

CELO and hypergeo are two projects which are the closest match in one way or the other to our proposal. CELO project tries to build a similar system to ours but their approach is different. On the other hand hypergeo's application is totally different from ours but the approach is close to what we would be using.

In contrast with CELO project, we would be measuring the spatio temporal user information in an autonomic manner. We aim to use GPS that will provide time stamp information in addition to the location information of the cell-phone and hence this time stamp information can be a source for modeling the spatiotemporal user density at the server. GPS and A-GPS provide highly accurate location information matched by none of the terrestrial methods. Assisted GPS technology makes it possible to receive GPS satellite data even at signal levels below known thresholds, allowing in some cases the estimation of users' positions even when user is indoors. Furthermore, We would be using state of the art (e.g. android) handsets to carry out spatio-temporal measurements in an autonomic manner.

As far as hypergeo application is concerned, from the perspective of RF optimization, the prototype is impractical. Our approach would be similar to the one used in hypergeo and we aim to develop a RF optimization system to gather location coordinates and time stamp information along with RSSI using GPS and then develop and demonstrate a data transmission procedure to the central data base. The server would be able to perform evaluation, validation, reliability, confidentiality and integrity of the acquired data.

The existing methodology for network optimization also includes extensive drive-tests. Drive-testing is a method to measure the Quality of Service, coverage and capacity of a network. In it a vehicle equipped with the necessary measurement equipment is driven around a geographical area and data is obtained. Using this data wireless carriers can analyze the network performance in a given area and make necessary changes. The data obtained during drive-test can include information such as signal quality, dropped calls rate, handover information, QoS information, etc.

The proposed approach improves upon the drive-testing methodology in a number of ways. Firstly, drive-testing requires an individual with a vehicle equipped with measurement equipment. This in itself can be a huge financial burden on operators. In contrast the proposed approach does not require any dedicated individual as information would be sent automatically by actual users. This would minimize the man-power considerably as compared to the existing solution. This factor and the lack of dedicated equipment requirements result in significant OPEX savings for operators.

Drive-testing is a methodology that works on one sample measurement taken at a particular instance of time. Any changes that may occur over different times of the day or week cannot be incorporated. As the number of users on the network is likely to change with time and affect the network performance, this is a serious limitation of the approach. Our approach improves upon this by providing spatio-temporal data to the operators which would include information of changing parameters with time. Statistically valid data would be provided to the operator which should help in making more informed decision as regards actions to be taken. As a result a holistic picture of RF conditions would be obtained as opposed to the selective nature of information obtained using drive-testing.

One limitation of drive-testing that is overcome in the proposed solution is the fact that data obtained using drive-testing is not user-centric. It is not obtained from real users operating in a day-to-day environment. Moreover in drive-testing indoor data cannot be obtained. Hence from the purpose of user experience drive-testing does not give the complete picture. As a result only typical field parameters indication can be relied upon using drive-testing whereas the proposed solution provides flexibility as regards the performance indicators.

The amount of data available through our methodology is significantly more that available through drive-test in terms of volumes of cases. Coverage maps would be generated. This would enable engineering teams to better comprehend the problem and devise very specific solutions (keeping customer location in mind). Network tweaking would be done by engineering teams. This is there by design, since solutions are more about trade-offs. So human interaction can reduce the otherwise, ping pong actions on network while catering competing problems.

Survey of existing technologies

A wide coverage is a key factor for the users of mobile cellular networks. The transmitted signals may not reach everywhere due to the nature of propagation of radio waves. The availability of coverage generates revenue in return. For these reasons site planning is carried out before installation of network, to find the best suitable places for BTSs to provide maximum coverage. But problems like availability of real state force non optimum placement of antennas. As a result, other mechanisms are adopted to improve coverage.

The system architecture of a conventional wireless communication consists of Mobile Switching Center (MSC), Base Station Controller (BSC) and Base Transceiver Station (BTS). MSC is connected to different BSCs through wired medium. The BSCs are often co-located with one of the BTSs within the group of BTSs it controls and communicates with them over A-bis interface. The users in the range of BTS avail its services. BTS can be used to provide coverage from 500 m to 10 km depending upon the environmental conditions. Different MSCs are connected to each other as well as to Public Switched Telephone Network (PSTN) and Packet Switched Data Network (PSDN) for connecting to rest of telephone network. The structure of a GSM network is elaborated in Fig. 1.

The process of monitoring, verifying and improving the performance of the radio network is called Optimization. It plays a major role in pre-installment and post installment of network due to the continuous growth of subscribers and traffic. Once the network is designed and operational, its performance is monitored for the quality assurance. Key performance indicators (KPI) are chosen for this purpose. The following figure depicts the flow of this process.

There are several performance indicators for monitoring different aspects but Key Performance Indicators (KPIs) for voice quality are Bit Error Rate (BER), Frame Error Rate (FER) and Dropped Call Rate (DCR). The performance monitoring process consists of key parameters for monitoring and performance parameters assessment. At first the collection of information parameters are required for monitoring. The KPIs are collected along with the field measurements such as drive tests. Drive test is the procedure to attain the actual feel of network coverage by driving through different paths and monitoring the service through test equipment i.e. test mobile, GPS equipment and laptops. The network management system also provides parameters measurements. And finally, when ‘faulty’ parameters have been identified and correct values are determined, the radio planner puts them in his network planning tool to analyze the change before these parameters are actually changed/ implemented in the field.

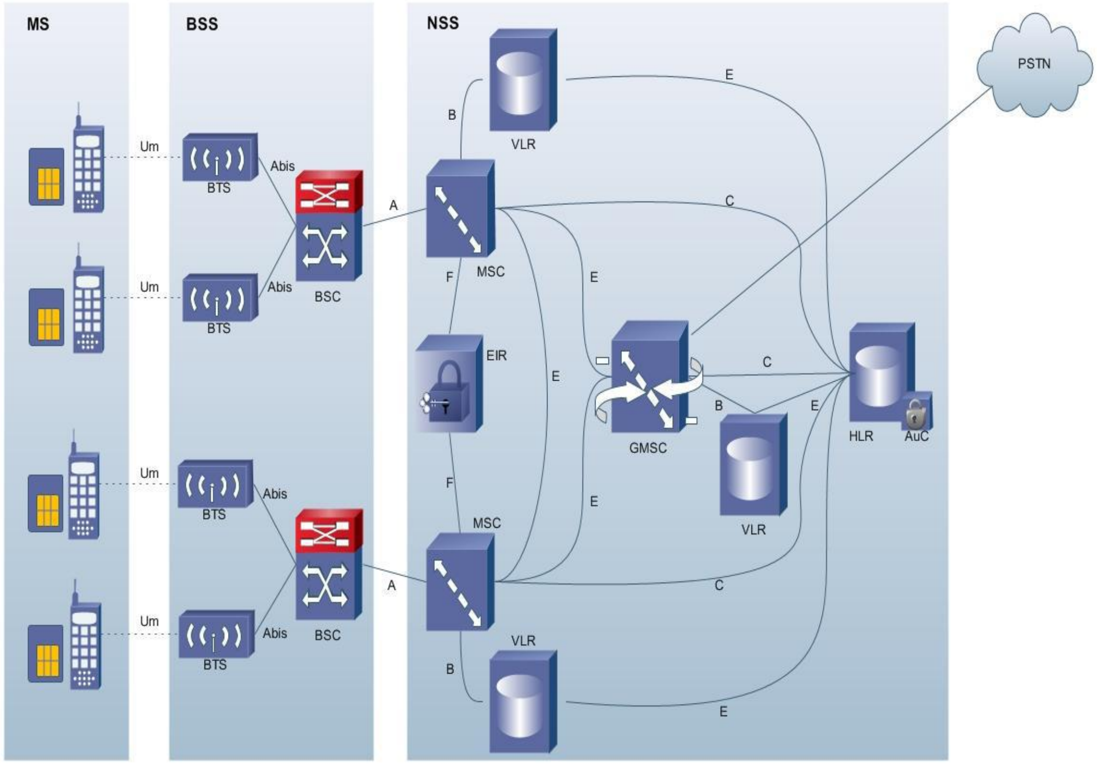


Figure 1: Structure of GSM Network

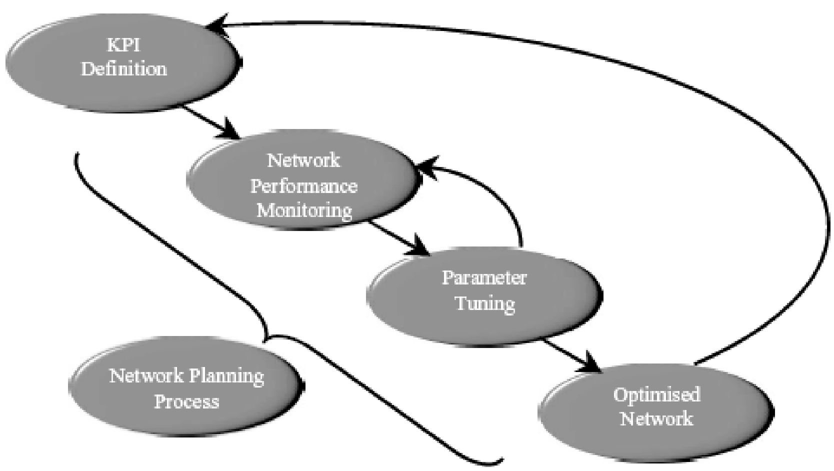


Figure 2 Network optimization: process flow diagram

Fig. 2 summarizes the network optimization process. Briefly, based on independent location and temporal information of mobile stations, drive tests are carried out to evaluate the network performance and then the results are used to perform optimal resource allocation.

Recent research indicate the use of spatial and temporal user density models for the efficient resource allocation and adaptive network planning. Mobile stations are equipped with an application to update their location information periodically or non-periodically to the network operator. Network planning and resource allocation is done based on this information to increase resource efficiency. Current network implementations greatly use the spatial user density models or temporal user density models to avoid resource wastage, while optimization is being done by evaluating the above mentioned KPI's. However, spatio-temporal databases have not yet been adopted in the market for optimization purposes. Test equipment used in the market for GSM optimization purposes include:

1. A test mobile phone
2. Scanning receiver
3. Transceiver system
4. Antennas
5. GPS
6. Visual display unit
7. Microphone
8. Loudspeaker box
9. Laptop computer

A detailed overview of drive test equipment used for optimization purposes is given in [34].

Disadvantages of Existing solutions:

In a conventional communication system, several problems are faced during the data collection process for the network monitoring. Networks are routinely monitored to detect RF holes. The wireless network operators perform pre-commercial optimization using test equipment and test drives and post-commercial optimization using drive tests and regularly scheduled visits to equipment sites. Alarms and sensor are also used within the fixed infrastructure equipment. Diagnostic software is used to generate the performance reports. The least important procedure is to rely on customers' complaints. All of the above mentioned procedures have disadvantages as described below.

Pre-commercial optimization procedure is carried out when the system is not installed which makes it static and not applicable to account for different loading conditions. Also the above tests are carried out by the assumption of much simpler terrain and environment when compared to the actual environment. These issues make the above procedures inaccurate.

Post-commercial optimization procedure provides very limited view of the whole network. By the time information is gathered, traffic loads and patterns may have changed. Visits to equipment sites are expensive and do not provide whole system view from a customer's perspective. The exceeding complexity of wireless networks limits the effectiveness of alarms and sensors. Finally waiting for the customer complaints is really an unfavorable option.

Sub-optimal positioning of BTS on the basis of time invariant spatial user density model leads to inherent loss in the signal strength. Using the spatial and temporal models independently, improves the system performance, but it may not provide sufficient information about the user density. For example a network planned on the basis of user spatial model may change with time, the user density may increase or decrease with time leading to lack/wastage of resources for a particular configuration. Temporal models considered alone also place situations of this type.

The current location based resource allocation algorithms do not provide the user with a facility to evaluate the performance of their own networks.

These problems can be overcome by considering the joint spatial-temporal information, known as spatio-temporal user density which is premise our project would build on. For the measurement of the location, we would make use of the GPS service. Over the course of the last two decades the Global Positioning System (GPS) has become the most extensively used positioning and navigation tool in the world. Its application ranges from surveying and mapping to military and geosciences. Although its positional and elevation accuracy is error-prone due to a number of factors [22], but its accuracy can be improved by using hybrid techniques. The success of GPS in deployment on mobile devices is attributed to its low-cost and lightweight nature. As a result of this Geospatial (accurate location, speed and time) data can be obtained by mobile users in real time. Newer model cell phones are GPS-enabled, resulting in a surge in applications that rely on GPS data. However, raw location data such as GPS coordinates is usually meaningless to the user without any location inference mechanism [23]. The user needs to attach some meaningful and useful semantics to such locations.

In case of mobile phone tracking, a number of options exist, which make use of cell site information, WiFi or GPS in general. For our system though, we chose GPS to get real-time location from the handheld device. The standard GPS has a spatial accuracy of around 2 to 10 meters, although higher resolution is possible as well [24]. The temporal accuracy of GPS in some cases has a standard deviation of 2.7725 seconds based on a Gaussian error distribution [25]. The inaccuracy of GPS in time is offset by making use of this standard deviation. In case of the iPhone, A-GPS (Assisted GPS) gives better and more accurate location information as compared to WiFi and Cellular cell site tracking approaches [26]. Assisted GPS (A-GPS) can also be incorporated to tackle the shortcomings of GPS. Assisted GPS minimizes the amount of time and information required from the satellites by providing information through an alternative communication channel [27].

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