A Review of Cellular Network Mobility Management :The Pathway to 5G Technology

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Abstract

A key component of mobile computing is location management, which includes tracking and registering mobile terminals inside a mobile network. The act of recording the location is called "location update," and the process of exploring it is called "paging." There are several ways to manage location, such as mobility-based strategies, data replication-based strategies, signal attenuation during tracking, and time-, zone-, and distance-based strategies for location updates. This study compares and analyzes current location management systems, paying special attention to how much money each one uses. Lastly, significant issues regarding location management for mobile networks of the future are discussed.

Keywords: GSM, Paging Energy-Efficient Location Sensing, mobile computing, location management.

1.Introduction

The service area of a Personal Communication Services (PCS) network is divided into multiple geographic zones [1–5]. Every location area (LA) is made up of multiple base stations. A base station's (BS) coverage area is referred to as its cell. Mobile terminal (MT) location data is kept up to date in two different types of databases: Visitor Location Register (VLR) and Home Location Register (HLR). Location management is the practice of monitoring an MT's whereabouts [6–10].Location registration and paging are the two primary procedures that make up location management [11–14]. In order to reduce location registration and paging costs, we have examined a variety of location management techniques in this study, along with their benefits and drawbacks. The expense is quantified in messages or bytes. The mobile terminal (MT) procedure reporting its present position for registration is referred to as a "location update"[15-19]. A location update is performed each time an MT enters a Location Area (LA) [20–24]. To facilitate the delivery of an incoming call to an MT, knowledge of the MT's present location is essential. Location updates [25-29] are executed through one of three approaches:

a. Sending a location update with every change of a cell entails performing a location update each time a mobile terminal (MT) transitions into a new cell area. This scheme comes with the subsequent pros and cons:

- Benefit ,There's no need to page.
- High signaling traffic burden as a result of frequent location changes is a drawback.

b. Every time an incoming call needs to be routed to a mobile terminal (MT), the network must be paged across all of its cells. The following are the benefits and drawbacks of this strategy:

- Benefit, No requirement for location updates.
- One drawback is the high signaling traffic burden brought on by the network's whole cell paging.

c. When a mobile terminal (MT) moves to a new sub-region, it notifies the network of its current one. This process divides the network into paging sub-regions. Only the cells in the current sub-region are checked to find the cell linked to the MT when an incoming call is routed towards them. The following prerequisites must be met for this approach:

- Implementation of a pagination process with lower traffic volume.
- Implementation of a technique for updating locations while reducing traffic.

The network begins the process of paging, or looking for the called mobile terminal (MT), as soon as an incoming call arrives. In Table 1, several paging process types are described:

a. Paging at the Terminal:

- *Description:* Identifies the precise location of a particular MT with relation to a call that has ended. The method pinpoints a group of cells that the MT might have gotten into.

- *Procedure:* When the MT answers within the timeout window, the paging operation is over; if not, a new set of cells is chosen for the next paging cycle.

b. Paging with Blankets:

- *Description:* When a call is received for it, simultaneously scans every cell in the current Location Area (LA) of the MT.

c. First-Paging at the Shortest Distance:

- *Description:* begins with the most recent updated cell and searches for the MT in a shortest-distance first order. The number of cells traveled from the most recent updated position is used to calculate the distance.

d. Based on the Probability of the User's Location, Sequential Paging:

- *Description:* predicts the MT's current location by using its location probability distribution.

e. Paging Velocity:

- *Description:* based on their velocity at the moment of location update, assigns users to velocity classes. The paging region is dynamically produced depending on the velocity class index and the last location update time when an MT call comes in.

f. Paging Across the System:

- *Description:* Pages every cell in the database when looking for a particular MT. The most expensive approach, despite being the simplest, has been dropped from use in the current cellular systems because to its exorbitant cost.

g. Area-Based Paging by Location:

- *Description:* looks through every cell in the MT's current LA. Several mobile phone networks have adopted this technique, which cooperates with the location area registration method and has an acceptable latency in field testing.

h. Selective Paging:

- *Description:* Involves an iterative process where a subset of cells is chosen for paging according to a preset criterion (e.g., distance) in each phase. When the MT is located, the paging process comes to an end.

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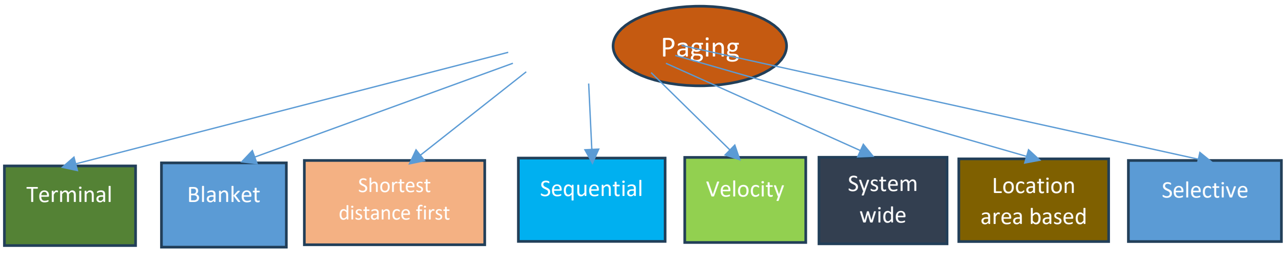

Figure 1 Types of Paging

Due to the large size of microcells, the quality of service (QoS) is notably poor, especially in indoor environments. To address this issue, microcells and picocells have been developed. A more recent addition to the field of mobile communications is the femtocell, designed to offer Future broadband wireless networks will provide affordable connectivity [30–32]. Femtocells play a crucial role in enhancing indoor voice coverage and data performance for all subscribers within their range [33–36]. Resembling a wireless router, femtocells are characterized by their compact size, allowing for low power consumption while improving QoS [37–40]. Operating in licensed spectrum, femtocells cover a range of approximately 10 meters and function as low-power wireless access points. They connect standard mobile terminals (MTs) to a mobile operator's network through residential DSL or cable broadband connections [41–46].

Through a thorough review of the literature, the current chapter addresses a variety of topics and strategies related to location management and enhancing its effectiveness. The background material is provided by the latest literature review, which takes into account the studies published after 2000 during the last 20 years. The source and quantity of citations from each source are listed in Table 1.

SL No	Source	Citation	SL No	Source	Citation
1	Expert System With Application	5	15	IEEE Transaction on Parallel and Distributed System	6
2	Renewable Energy	4	16	Computer Network	5
3	Information Sciences	8	17	Journal of Indian Inst. Science	5
4	Computer and Industrial Engineering	4	18	International Journal of Innovative Computing, Information and Control	5
5	Journal of Multivariate Analysis	3	19	IEEE Communication Letter	4
6	Applied Mathematical Modelling	5	20	IEEE Transaction on Wireless Communication	5
7	The Institution of Engineering and Technology	6	21	IEEE Journal on Selected Areas in Communication	3
8	Transportation Research	8	22	IEEE/ACM Transaction on Network	3
9	Computer Environment and urban system	3	23	IEEE Transaction on Systems, man and cybernetics	3
10	IEEE communication Magazine	5	24	IEEE Transaction on Audio, Speech and Language Processing	3
11	Neuro Computing	7	25	IEEE Transaction on Instrument and Measurement	

12	Computer Communication	7	26	IEEE Transaction Industrial Electronics	2
13	Computer and Operational research	4	27	IEEE Transaction on Neural Network	3
14	Journal of Parallel and Distributed Computing	6	28	Applied Soft Computing	3
Total		75		Total	50

Table -1 Citation

The literature review provides enough information regarding current issues to identify the gap in the existing work and advancement in solving the problems by way of minimizing the difference emphasizing relevance to the present work.The literature reviewed falls into several general categories, including the evolution of mobile networks, cellular network architecture, statistical analysis and neural network predictors forsubscriber prediction, evolutionary algorithms for static management of cellular networks, and profile-based paging for dynamic management of cellular networks. Every one of these categories relates to the way a system-model was designed with mobile network issues in mind. The percentage of papers surveyed for each category is shown in Figure 2. A brief overview of these issues is given in the following sections.

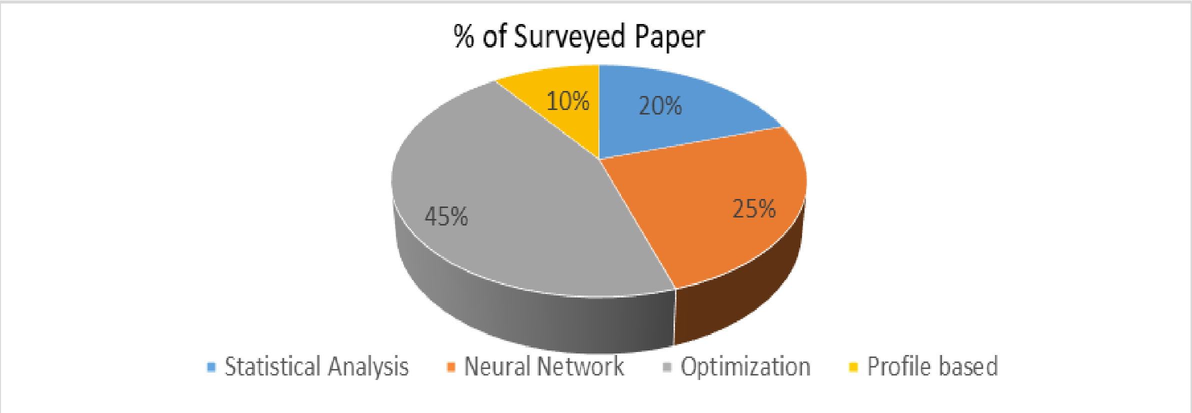

Figure-2 Percentage of Survey Paper

The relative impact of cellular network characteristics on user satisfaction with overall network quality and optimization is the problem this work attempts to solve. The last ten years have seen more rapid transformation in the communications industry than any other decade. Less than one in six persons worldwide lacked access to a telephone in 1999, more than a century after the invention of the device. As illustrates, by 2009, seven out of ten people worldwide had access to mobile phones.

In recent times, the Indian mobile industry has experienced tremendous growth and has amassed over half a billion users, making it one of the nation's greatest success stories. With the rapid advancement of technology, 616 million unique customers are expected to be subscribed to mobile services by the end of 2023, with India ranking as the world's second-largest mobile market (http://www.gsmamobileeconomy.com/india-new/). More than 25% of the anticipated mobile customers in the Asia-Pacific region would come from India by 2023. According to the Mobile Economy: India 2016 report, India is experiencing a rapid ongoing technological shift in light of better affordability, better network coverage, and falling device prices. These developments will contribute to the addition of over 350 million new mobile subscribers by 2023, bringing the country's connection penetration to slightly over 100%, as shown in Fig 3

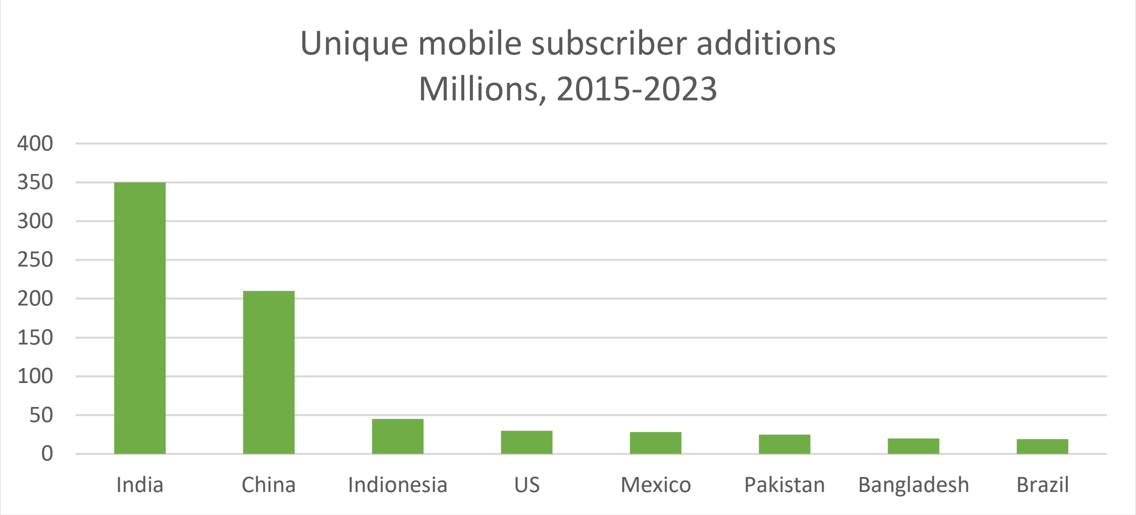

Figure -3 Mobile subscriber additions

2. Strategies for location management

2.1 Traditional GSM network location management

In [1], a method for managing location is introduced, wherein The traffic load on Signaling System Number 7 (SS7) is linked to the Global System for Mobile Communications (GSM), a pan-European standard, to enable the mobility of the Mobile Terminal (MT). The creation of SS7 traffic in GSM is mostly associated with necessary tasks like as position updates, inter-Mobile Switching Center (MSC) handovers, and call setups [1]. The SS7 bytes created every transaction are compared to the total traffic load directed to the SS7 network in order to determine call origination and termination frequencies, handovers, and location updates per hour. The Visitor Location Register (VLR) in the conventional GSM process duplicates all relevant data for this Mobile Terminal (MT) from the Home Location Register (HLR) whenever it enters a new Location Area (LA) [13]. The cost of accessing databases at the Home Location Register (HLR), the new Visitor Location Register (VLR), and the previous VLR is one of the many charges related to location updates. Furthermore, the price includes messaging transmission costs via fixed and wireless network links. [13]. For the purposes of registering and deregistering from the old VLR and new VLR, the procedure uses four messages for requests and acknowledgments. The location update cost can be computed using the following formula: [13] if C_{HLR} is the cost of accessing the HLR, C_{VLR} is the cost of accessing the VLR, C_{MF} is the cost of sending messages through the fixed network, and C_{MW} is the cost of sending messages through the wireless network.

$$Cost_{lu\text{-}gsm} = 2C_{VLR} + C_{HLR} + 4(C_{MF} + C_{MW}) \quad (1)$$

Two messages are required for the paging process: one to transmit the request and the other to receive an acknowledgment. This allows the mobile terminal (MT) to be tracked, which helps in call delivery. Accessing the Home Location Register (HLR) as well as the Visitor Location Register (VLR) is required for this. As such, the method described in [13] is used to calculate the paging cost.

$$Cost_{pg\text{-}gsm} = C_{VLR} + C_{HLR} + 2(C_{MF} + C_{MW}) \quad (2)$$

If λm is the MT movement rate and λc is the call arrival rate, then [13] gives the total location management cost..

$$Cost_{lm\text{-}gsm} = \lambda m Cost_{lu\text{-}gsm} + \lambda c Cost_{pg\text{-}gsm}. \quad (3)$$

Through a thorough review of the literature, the current chapter addresses a variety of topics and strategies related to location management and enhancing its effectiveness. The background material is provided by the latest literature review, which takes into account the works published after 1990 throughout the last 20 years. The source and quantity of citations for each source are listed below.

2.2 Multiple-layer location update protocol

In order to decrease short-term switching instability and efficiently distribute position updating signal traffic among all cells, a technique known as the multilayer location update (MULTI) is proposed in [2]. This strategy uses two main techniques:

(i) MULTI-Grouping (MULTI-G): This technique divides Mobile Terminals (MTs) into multiple groups and assigns each group to one or more levels. Interestingly, different groups' cells are accessible by MTs for location updates. As a result, location updating signal traffic is distributed among all cells.

(ii) MULTI-Switching Layer (MULTI-S): This technique links MTs in every group to several area layers. An update to a separate layer is indicated by an MT switching to a new layer to start a location update. By adding hysteresis to location updates, MULTI-S successfully mitigates short-term switching instability.

Together, these two techniques provide the MULTI approach, which introduces hysteresis to control short-term switching instability and offers a mechanism to distribute location update signal traffic equitably.

2.3 Recent developments in mobile cellular technology

In the contemporary landscape, mobile cellular phone technology stands as the cornerstone of society, orchestrating a profound transformation in the realm of communication through technological advancements and diverse applications. The pervasive integration of these techniques has not only redefined communication but has also significantly enhanced the overall lifestyle of the general populace. This technological evolution has become instrumental in shaping a more interconnected and accessible world, contributing to the well-being and convenience of individuals in society.

The concept of a wireless network once held an almost mystical allure in the imaginations of our predecessors, but Marconi shattered the notion of impossibility with his invention of the wireless telegraph in 1895. Recognizing the commercial potential for a telegraphy system free from the constraints of physical wires, Marconi laid the groundwork for a revolution in communication.

Fast forward about five decades, and the invention of the transistor marked the birth of portable communication. What was once a seemingly impossible dream became a reality. Today, the use of cellular telephony has evolved into a smart and commonplace aspect of our lives, characterized by the convenience of making and receiving calls at will, anytime and anywhere.

In the current "information age," individuals, especially frequent travelers and businesspeople, prefer utilizing cellular networks over fixed terminals such as small PCs or laptops. These portable computers, aptly termed "MOBILE," enable users to send and receive faxes, emails, and various forms of data while on the move. In essence, mobile phones, as we know them today, have not only transformed our lifestyles but have also become an indispensable and integral part of our daily existence.

The origins of the mobile phone are intriguing, and credit must be given to Alexander Graham Bell in St. Louis, USA. He is recognized as the pioneer who launched the first commercial mobile telephone system in 1946. The introduction of the concept of the Base Station had a revolutionary impact on the mobile phone industry.

The evolution of the mobile phone was swift, as the initial use of a large singular transmitter at the base station was soon supplanted by the cellular concept developed by BELL Labs. This innovation facilitated a larger subscriber base and extended range by employing frequency reuse and handoff schemes. The shift from amplitude modulation to digital keying techniques addressed the challenge of accommodating a large number of users within the constraints of limited bandwidth.

In a noteworthy development, the Nordic Mobile Telephone (NMT) outpaced the U.S.-based BELL Labs by introducing commercial cellular services to the market in 1981 in the Nordic countries. This marked a significant milestone in the global proliferation of mobile phone technology.

When the idea of "GENERATION" emerged, the history of cellular communication achieved success.
Figure 4 depicts the evolution of cellular standards and cellular technology:

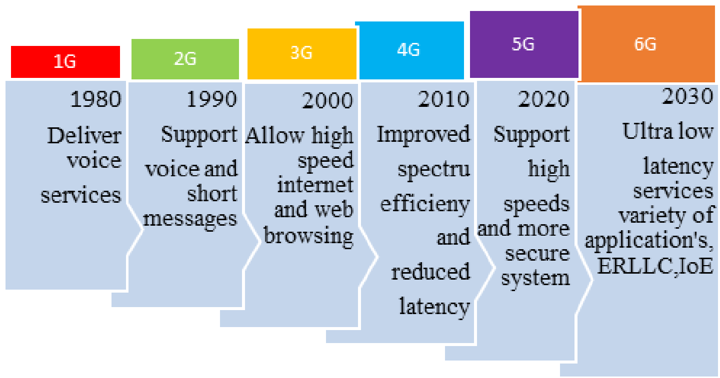

Figure -4 Generation of Cellular Technology

2.4. A location tracking technique based on signal attenuation

A location tracking method based on variations in downlink signal attenuations is shown in [8]. This technique tracks a mobile device's location by analyzing changes in the downlink signals' attenuation.A different method of position prediction based on sophisticated propagation models is provided in [9]. This plan uses advanced models to anticipate a mobile device's position.A distributed location management approach is put out in [23]. Using this method, location information databases are numbered sequentially and arranged into a sliding-frame with weights. Nevertheless, there are issues with this approach, such as the creation of redundant data. It also takes a long time because the first location region IDs used in the search for location data are chosen at random. A scheme based on the quantity of beacon packets that power-controlled Mobile Terminals (MTs) periodically send is proposed by [24] for three-dimensional location estimation. This method makes use of beacon packet transmission to determine a mobile device's approximate three-dimensional location.

2.5 Location Management

In the realm of location management, mobility stands as a crucial phenomenon in the functioning of wireless personal communication networks (PCNs). The term refers to the ability of users or devices to move within the network while maintaining connectivity and access to various services. Given the remarkable surge in demand for mobile services and applications, numerous companies and service providers are striving to offer fully integrated services. These services encompass a range of features, including traditional voice communication, Voice over Internet Protocol (VoIP), fax services, live video streaming, and music streaming, among others. The objective is to attract a larger user base by providing a diverse and comprehensive array of services. Recent advancements in the design of wireless networks and mobile computing environments have paved the way for seamless connectivity. These innovations contribute to a more fluid and continuous user experience, enabling individuals to stay connected and access various services regardless of their location within the network.

Indeed, mobility management is a complex concern that plays a pivotal role in the foundational design of wireless cellular networks. The ability to accurately determine a user's position in the network when a call arrives at the mobile terminal is crucial. Tracking the location of users poses a significant challenge in mobility management.Especially in scenarios where profit margins are thin, accommodating a large number of users in the wireless Personal Communication Network (PCN) becomes essential. This accommodation should ensure a prompt and effective response without compromising the quality and availability of received signals.

Mobility management can be broadly categorized into two main processes:

Location Management: This involves tracking and managing the location of mobile users within the network. Efficient location management is crucial for determining the whereabouts of users when they receive calls or initiate communication. It addresses challenges related to tracking users' movements and ensuring that the network can effectively locate them.

Handoff Management: Handoff, also known as handover, is the process of transferring an ongoing call or data session from one cell to another without interruption. Handoff management is essential for maintaining seamless connectivity as users move across different cells within the network. It focuses on optimizing the handover process to ensure continuity and quality of service.

Both location management and handoff management are integral components of mobility management, contributing to the overall effectiveness and reliability of wireless cellular networks.

2.5.1 User Location Prediction

User location prediction refers to a set of technologies employed to forecast the geographical location of a mobile user with minimal error, prioritizing high performance. This predictive information is utilized for a variety of services, including emergency response, radio resource management (such as handoffs), and mobile traffic management. The impetus for significant advancements in this sector was provided when the USA Telecom authority mandated mobile service providers to furnish location data for swift E-911 emergency response.

The technologies used for determining user location can be broadly classified into two groups:

Handset-based: In this approach, the mobile device itself plays a key role in determining its location. This often involves leveraging technologies such as Global Positioning System (GPS), Wi-Fi positioning, Bluetooth, or sensor-based methods within the handset. The device collects data and calculates its position, providing accurate location information.

Network-based: Network-based approaches rely on infrastructure elements within the telecommunications network to determine the user's location. This can involve utilizing data from cell towers, signal strengths, or triangulation methods. Network-based methods are often used when handsets lack specific positioning capabilities or for scenarios where improved accuracy is required.

Both handset-based and network-based technologies contribute to the effectiveness of user location prediction, catering to different scenarios and addressing diverse requirements in areas such as emergency services, resource management, and overall network optimization.

2.5.2 Location management schemes

Location Update and Paging are the two main procedures that make up Location Management [2]. While paging is sometimes referred to as "location lookup" or "search," location update is sometimes referred to as "registration" or "location registration" in research studies [3]. The User Equipment does the Location Update, informing the network of the user's current location. The Base Station, which surveys a location where the user may be present, is responsible for paging.

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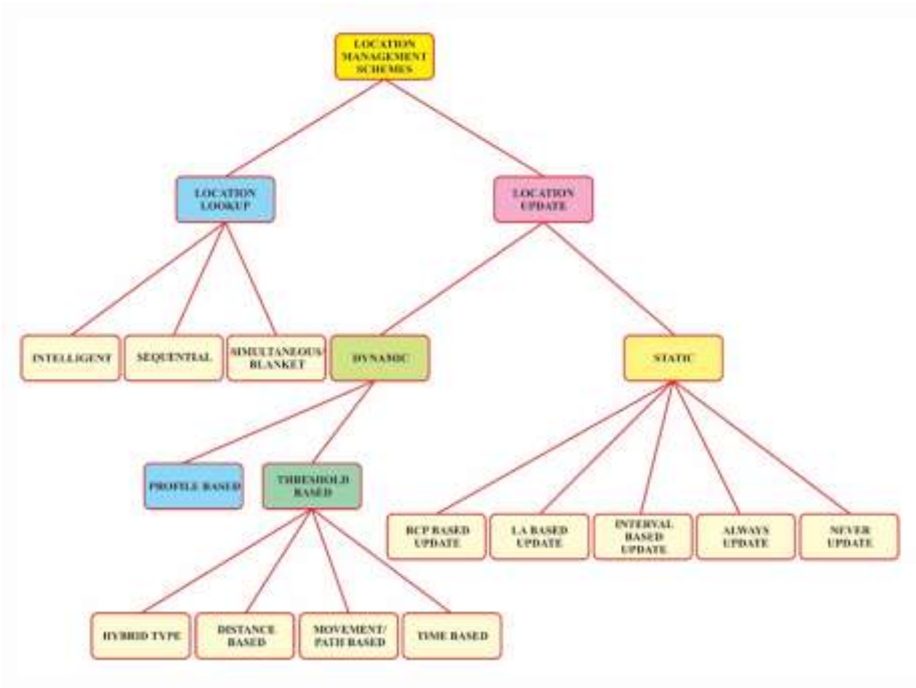

Figure -5 Location Management Schemes

The concept of location management schemes in mobile networks encompasses two primary processes: static and dynamic.

Static Process Characteristics: In the static process, a predetermined set of cells is designated in a contiguous region. Location Registration (LR) or location updates are generated by the mobile station irrespective of the user's mobility. The static method is determined offline, meaning that the system's configuration is established beforehand. Paging is relatively uniform for all users and lacks personalization [7, 37, 2, 10, 51, 52, 39, 15, 11, 40–44, 34]. This approach may not adapt well to varying user mobility patterns, as it does not tailor location updates based on individual user behaviors.

Dynamic Schemes Characteristics: Dynamic schemes involve generating location updates in a highly personalized manner for each user. Various possible architectures govern different users within the network [3, 8, 9, 12–14, 16–23, 25–28, 30–33, 35, 36, 46–48, 50, 53, 55, 56].Dynamic schemes may require a higher degree of computational capabilities within the network.Despite the computational demands, dynamic schemes are often more effective than static schemes, as they can adapt to individual user mobility patterns and achieve better results [3, 8, 9, 12–14, 16–23, 25–28, 30–33, 35, 36, 46–48, 50, 53, 55, 56].

In summary, dynamic systems offer a personalized and adaptive approach, perhaps yielding superior results at the expense of additional computational requirements, whereas static processes offer simplicity with fixed cell sets and uniform paging. The specific requirements of the mobile network and the intended balance between efficiency and adaptability are generally the deciding factors when choosing between static and dynamic designs.

2.5.2.1. Static management strategies

The static location management schemes, as reviewed in [39, 15, 11, 40–44, 34], simplify the complexity of user individuality. The prominent static schemes include Each mobile terminal updates its location whenever it enters a new cell boundary. Reduces paging cost but incurs a high lookup cost due to frequent updates.

Never Update Strategy: A location update is performed for each mobile terminal, and for incoming calls, the search is only for the intended user. Low resources used for search, but high gap in user location retrieval, especially inefficient in cluster scenarios.

Location Area (LA) Scheme: Cells are grouped into location areas (LAs), providing a layer of abstraction. Reduces paging load by paging the last updated location area for an incoming call. Location updates triggered at symmetric intervals or LA boundary crossings, with periodic transmission of location update signaling messages. The ping-pong effect, involving frequent movement between boundaries of two or more LAs, leading to a high number of location updates with low physical mobility[57-60].

Reporting Cells (RC) Scheme: Proposed by, Bar-Noy and Kessler. Bounded and unbounded approaches. Demarcates cells as reporting or non-reporting, requiring a self-aware paging scheme for the unbounded approach. Limited performance, requiring additional location overhead. Determining an optimum set of reporting centers is an NP-complete problem, making arrangement challenging even with network knowledge. These static schemes represent various trade-offs between paging cost, lookup cost, and efficiency, with each designed to address specific challenges in user location management within mobile networks.

2.5.2.2 Dynamic management strategies

Dynamic strategies in location management are considered more complex, requiring increased computational effort as they take into account different network topologies on a per-user basis. These dynamic strategies are designed to adapt to individual users' call patterns and movement patterns. Two extremes in user behavior are often considered: the occasional mover and the frequent mover.

Occasional Mover: The occasional mover rarely updates its location explicitly.This type of user might not trigger frequent location updates, relying on the network to handle their infrequent movements. Strategies for occasional movers need to balance the need for location accuracy with the avoidance of unnecessary location updates.

Frequent Mover:The frequent mover updates its location more regularly, often when crossing into a new boundary area or Location Area (LA) [61-62].This type of user triggers location updates more proactively to ensure the network remains aware of their current location.Strategies for frequent movers need to efficiently handle the higher frequency of location updates while minimizing associated costs.Dynamic Techniques Dependent on User's Behavioral Pattern:

Mapping Call Patterns: Analyzing a user's call pattern to predict their likely movements and optimize location updates accordingly. Enhances the accuracy of location prediction by considering the user's historical call behavior.

Mapping Movement Patterns: Considering the movement patterns of users to predict their likely locations and optimize location updates. Improves the efficiency of location management by adapting to individual users' mobility behaviors.

Dynamic strategies in location management aim to strike a balance between the computational complexity of considering individual user behaviors and the optimization of location updates for both occasional and frequent movers. These strategies play a crucial role in enhancing the adaptability and efficiency of mobile networks in handling diverse user patterns and movement behaviors [63-65].

2.6 Identification of the Problem

The consideration of dwell time distribution introduces a novel perspective to location management in cellular networks. Traditionally, works in this domain have focused on optimizing total cost, addressing parameters like paging delay, and employing meta-heuristic algorithms. However, by evaluating the relative performance of each network over time, it becomes possible to enhance overall efficiency further.The introduction of the Dwell Time Distribution brings attention to several key points:

Cost Function Composition: The cost function encompasses both update cost and paging cost.A factor of percentile dwell time is included, which adds a dimension of relative ranking based on network performance.

Percentile vs. Percentage: Percentile differs from percentage values in that it doesn't require absolute values. Instead, it settles for relative ranking based on the performance of other networks, the same network at different times of the day, or other users sharing the same network.

Importance of Percentile Calculation: Telecom companies, in certain scenarios, may not aim to be the highest-performing ones, as this could incur significant costs. Instead, the goal might be to perform above a minimum threshold of quality of service relative to less efficient counterparts.

Performance Benchmarking:Relative performance based on percentile dwell time provides a benchmark for evaluating network efficiency and effectiveness. This approach is particularly relevant when the objective is to meet or exceed a minimum quality of service threshold compared to less efficient networks.

By incorporating the concept of percentile dwell time into the cost function, mobile network optimization efforts can be aligned with the relative ranking of performance, allowing telecom companies to balance service quality and cost-effectiveness effectively. This approach provides a nuanced perspective on performance evaluation, acknowledging the importance of relative benchmarks in the dynamic landscape of cellular networks.

- Therefore, when a person's mobile device wants to update its location, Dwelling Time within the current L.A. ($T_{L.A}$) as a parameter, we shall use "percentile dwell time" (T_{pd}), It is the portion of dwell time in that cell that is less than the dwell time.

- All radio transceptions require power, which adds to the expense. By optimizing the cost function, location management plays a crucial role in lowering network load and costs. The cost function that most scholars agree upon is provided by

$$Cost= \beta \times N_{LU}+N_P \qquad (4)$$

Where N_{LU} is the total number of location updates, N_P is the total number of paging performed and β is a constant to weigh the relative cost of L.U compared to Paging.

- The total of L.U. and Paging cost equals L.M.'s cost. The calculation of paging cost involves multiplying the cost per paging message by the number of cells and the call rate (λ). Cost per L.U. divided by time spent residing in the current L.A. equals L.U. cost.

2.7 Utilizing Statistics to Assist with User Prediction

The passage discusses the importance of time series analysis in various engineering fields, particularly in the context of forecasting non-stationary signals. The focus is on location management issues in mobile cellular networks, an area that has been less explored.

The Box–Jenkins method, utilizing autoregressive moving average (ARMA) linear models, is mentioned as a traditional approach for time series analysis. However, it is highlighted that this method has shortfalls, including the need for statistical information and the complexity of regular ARMA models. The limitations lead to the exploration of innovative nonlinear methods like Neural Networks. Neural networks are considered appealing due to their ability to predict outcomes without requiring a predefined model, making them suitable for forecasting.

The passage emphasizes the significance of ARIMA (autoregressive integrated moving average) modeling as a reference for benchmarking Neural Network studies. Back-propagation, a type of neural network, is compared with ARMA models, demonstrating the superiority of neural networks in long-term forecasting using short-term input.

The challenges in forecasting, such as the need to define numerous variables and manually navigate the learning curve of algorithms, are acknowledged. The passage introduces the idea of hybrid models that combine the strengths of individual models to improve forecasting accuracy. It mentions examples of hybrid models, such as ARIMA combined with support vector machines (SVMs) for forecasting stock prices and seasonal ARIMA (SARIMA) combined with SVMs for forecasting seasonal time series.

In conclusion, the passage suggests that combining different forecasting models into hybrid approaches may yield better results than individual techniques. The significance of addressing challenges in forecasting, such as defining parameters and navigating learning curves, is highlighted. Overall, the text provides insights into the complexities and advancements in time series forecasting methods, particularly in the context of location management in mobile cellular networks.

2.8 Research methodology

2.8.1 Utilizing Optimization Methodologies for Network Optimization

The passage discusses the application of Evolutionary Algorithms (EAs) to solve optimization problems in the field of engineering. Optimization problems in real-world applications are often challenging to address through exact mathematical approaches due to factors like inapplicability or high computational costs. EAs, inspired by biological evolution, offer a population-based optimization approach, incorporating selection, reproduction, and survival of the fittest mechanisms.

Evolutionary Algorithms (EAs):EAs are optimization local-search algorithms based on a population and inspired by biological mechanisms.EAs involve selection, reproduction (mutation and crossover), and survival of the fittest.EAs efficiently explore the solution space to minimize the number of solutions required to find a quasi-optimal one.

Study Objectives: The primary aim is to study various EA techniques and explore new approaches for their improvement.EAs are applied to real-world problems and typical problems discussed in the literature to demonstrate their efficacy.

Evolutionary Computation: Evolutionary computation is a branch of computational intelligence inspired by the theory of evolution and survival of the fittest.

Population Dynamics: Individuals in the population undergo mutation and crossover to generate new offspring, with a biased selection process for survival.After several generations, the best individual represents a near-optimal solution.

Current Techniques:

Stochastic Search and Combinatorial Optimization: EAs, including genetic algorithms, swarm-based algorithms (e.g., particle-based algorithms, binary bat algorithms), and hybrid algorithms (e.g., hybrid PSO-GA, hybrid swarm), are employed to efficiently solve stochastic search and combinatorial optimization problems.

Challenges and Heuristic Algorithms:

NP-Hard Problems: Many optimization problems are proven to be NP-hard, making it challenging to find exact solutions.

Heuristic Algorithms: Heuristic algorithms, including approximation algorithms, are discussed as practical solutions for near-optimal solutions within a reasonable time.

Focus on Heuristics: The research focuses on heuristic algorithms without guaranteed solution quality, emphasizing their efficiency for real-world applications.

The passage provides an overview of the principles behind Evolutionary Algorithms, their application to optimization problems, and the challenges and considerations in selecting appropriate algorithms for real-world engineering scenarios. Experimental evaluation and the practical efficiency of heuristic algorithms are highlighted as key aspects of the research.

3. Future directions for location management in 5G

The passage discusses the challenges and future research areas in location management schemes. Two specific future scopes are outlined:

Energy-Efficient Location Sensing:

Current Scenario: Cloud computing is integrated into location-based services and applications, but such services often require high energy consumption.

Location-Based Application (LBA): LBAs, which obtain the user's current location and provide services like social networking and mobile commerce, contribute to high energy consumption.

Energy-Efficient Solutions:A low-power location sensing scheme for energy-efficient mobile tracking.An extension of EnTracked that focuses on energy-efficient trajectory tracking instead of position tracking.

CAPS: Cell-ID Aided Positioning System, a trajectory tracking scheme.

EnLoc: Energy Efficient Localization for mobile phones, utilizing Logical Mobility Tree (LMT) to record people's actual mobility.[58]

Research Focus: Despite existing strategies, the passage highlights the need for ongoing research in green, i.e., energy-efficient location management.

Location Management in 5G Mobile Networks:

5G Mobile Network Challenges: 5G networks deal with heterogeneity and involve the deployment of small cells (picocells and femtocells) within larger cells (macrocells and microcells), leading to dense network deployment.

Densification Challenge: Densification becomes a critical issue in 5G networks due to the deployment of numerous base stations (BSs).[59,60]

Location Update Challenges: The movement between densely deployed cells in 5G networks can lead to a significant number of message transmissions, increasing network traffic and location update costs.

Future Research Area: The passage suggests that the development of novel location tracking strategies specifically tailored for the unique challenges of 5G mobile networks is a promising future research area.

In summary, the future of location management involves addressing energy efficiency in location sensing applications and devising innovative strategies to handle the challenges posed by the densification and heterogeneity of 5G mobile networks [65-68].

4. Conclusion

Location management is a major issue in the realm of mobile computing. In order to provide the highest quality of service (QoS) to subscribers, accurate position tracking of MT is necessary for low-cost, low-latency call making. This paper examines the challenges in this industry by comparing and discussing many location management approaches that are already in use. First, the principles of location management are clarified. Because of the growing demand for personal communication networks and the increase in active mobile consumers, there are more location updates. This consumes a lot of bandwidth and shortens the phone's battery life in addition to heavy traffic. Numerous strategies are proposed to reduce the traffic generated by location updates. Every MT participating in these schemes has a profile that is updated with the MT's mobility data. This mobility information gives each MT the probability of moving in each network location area.

This makes it easier to anticipate the user's movement behavior and allocate resources more effectively. A mobility-based location management strategy uses the user's short- or long-term mobility information to track their whereabouts. Lowering the cost of location tracking is achieved by replicating the mobility data of the MTs at frequently frequented places. Each of these mobility- or replication-based plans has advantages and disadvantages of its own. These two groups of techniques are compared in this research. To enhance the quality of service for the vast majority of mobile users, especially in interior environments, femtocells are placed inside macrocells. Additionally, different location management systems for macrocell–femtocell based LTE networks are compared and evaluated in terms of cost and latency. The final section of this lecture examines potential future research directions in location management.

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