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A Handover and Mobility Management Scheme for 5G Communications

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ABSTRACT:

Wireless communication refers to the transfer of information or data between devices without the use of physical cables or wires. Wireless Communication has become an essential part of our daily lives,with a growing need for consistent, fast, and seamless connectivity. Handover is a core phenomenon in wireless communications. It is the process of automatically changing frequencies when a mobile device moves from one cell to a neighbouring cell. The widespread use of mobile devices and the introduction of various wireless technologies like 5G have introduced fresh challenges for handover operations. In this paper a clustering algorithm has been developed that resulted in the formation of transient cells based on the device signal strength and the proximity of neighbouring devices. The existing Mobility Management Schemes are not scalable with real life datasets. In this paper a HPC analysis scheme is compared with existing mobility management schemes Gaussian Mixture Model (GMM) and Distributed Mobility Management (DMM). The proposed Consolidation scheme can be integrated with GMM to support a huge number of devices to ensure seamless connectivity across the terrain.

Keywords: Wireless Communications, Handover, Clustering, Mobility Management

INTRODUCTION:

The development of 5G and future cellular networks is essential to accommodate a vast number of Internet of Things (IoT) devices while ensuring high-quality connectivity for all of them. These networks are expected to handle communication needs in situations involving high mobility, which doesn't only refer to the speed of moving devices but also the challenges associated with such movement. One challenge is maintaining a stable connection during handovers between network cells.

The difficulties related to mobility depend on factors like the speed and density of users, the size of the network cells, and the required network latency and quality of service (QoS). Examples of high-mobility scenarios include fast-moving trains, vehicular ad hoc networks, and communications with unmanned aerial vehicles (UAVs).

Moreover, 5G and future networks are expected to support real-time services for devices such as autonomous cars, drones, and other smart vehicles. These services demand precise location information with minimal latency to react in real-time. Unlike existing networks, which can search for a mobile user's location upon request, 5G and beyond networks may not always have that luxury.

To support these requirements, 5G networks will need to handle tens of billions of highly mobile devices while maintaining low latency and high location accuracy. There's a trade-off between the frequency of location updates and the uncertainty in a device's location. As a result, the signaling cost associated with mobility management is expected to be significantly higher in 5G and beyond networks compared to previous cellular networks. This cost increase applies to both the network infrastructure and each mobile device.

Furthermore, future networks are likely to use smaller cells organized hierarchically, including macro-cells, micro-cells, and femtocells. This hierarchical structure will further elevate the signaling cost related to mobility management compared to 3G and 4G networks. Therefore, there's a pressing need to find ways to reduce the signaling cost associated with mobility, especially when dealing with a large number of highly mobile devices.

MATRIX LABORATORY:

MATLAB, short for "MATrix LABoratory," is a powerful and versatile programming environment and computing platform widely used in academia, research, and industry. It was developed by MathWorks and is known for its robust capabilities in numerical and scientific computing.

MATLAB's significance lies in its ability to simplify complex mathematical and computational tasks. It accelerates research and development processes, reduces the likelihood of errors, and enhances productivity. Moreover, its widespread adoption ensures a wealth of resources, including a vibrant user community and a vast repository of user-contributed functions and scripts. MATLAB offers a comprehensive set of features that make it a preferred choice for engineers, scientists, and researchers:

Key features of Matrix Laboratory include:

- High-Level Programming Language: MATLAB uses a high-level scripting language that simplifies the creation and manipulation of arrays and matrices, which is fundamental to many scientific and engineering tasks.
- Rich Libraries: It comes with a vast library of built-in functions and toolboxes for various domains, such as signal processing, image processing, control systems, and machine learning, among others. These libraries streamline complex calculations and data analysis.
- Interactive Environment: MATLAB provides an interactive environment that allows users to execute commands, visualize data, and develop algorithms in real-time. This feature is particularly useful for rapid prototyping and experimentation.
- Graphics and Visualization: MATLAB includes powerful tools for creating 2D and 3D plots and visualizations. Engineers and researchers can use these capabilities to better understand data, present results, and communicate findings effectively.
- Simulink Integration: Simulink, a companion product to MATLAB, provides a graphical environment for modeling, simulating, and analyzing dynamic systems. The integration between MATLAB and Simulink is seamless and is widely used in control systems and model-based design.
- Image and Signal Processing: MATLAB is a go-to tool for image and signal processing tasks like image enhancement, filtering, and feature extraction.
- Communications and Wireless Systems: MATLAB helps design and analyze communication systems, including wireless networks and digital modulation techniques.

BASIC FUNCTIONS OF MATLAB:

MATLAB, a widely-used programming environment for numerical and scientific computing, provides a rich set of basic functions that form the foundation for performing various tasks in mathematics, engineering, data analysis, and more. These basic functions serve as building blocks for more complex operations and are essential for users to understand when working with MATLAB. Some of the basic functions of matlab are:

1. Arithmetic Operations:

- MATLAB can perform basic arithmetic operations like addition, subtraction, multiplication, and division using standard symbols (+, -, *, /).

- For example, `a = 5; b = 3; c = a + b; `will assign the value 8 to the variable `c`.

2. Element-Wise Operations:

- MATLAB can also perform element-wise operations on arrays or matrices.

- For instance, `A = [1, 2; 3, 4]; B = [2, 2; 2, 2]; C = A.* B; will create a new matrix `C` with element-wise products of `A` and `B`.

3. Exponential and Logarithmic Functions:

- MATLAB provides functions for exponentiation (`exp`) and logarithmic operations (`log`, `log10`, `log2`).

- For example, `x = 2; y = exp(x); `calculates `y` as the exponential of `x`.

4. Trigonometric Functions:

- MATLAB includes trigonometric functions like `sin`, `cos`, `tan`, as well as their inverses (`asin`, `acos`, `atan`).

- To calculate the sine of an angle in radians, you can use `angle_rad = pi/4; sine_value = sin(angle_rad);`.

5. Matrix Operations:

- MATLAB is particularly powerful in handling matrices. It can perform matrix multiplication (`*`), transposition (`'`), and inversion (`inv`) among others.

- For instance, to compute the inverse of a matrix `A`, you can use `inverse_A = inv(A); `

6. Statistical Functions:

- MATLAB provides a range of statistical functions for calculating mean, median, variance, standard deviation, and more.

- For example, `data = [1, 2, 3, 4, 5]; mean_value = mean(data); ` calculates the mean of the given data.

7. Logical Operations:

- MATLAB handles logical operations like AND (`&`), OR (`|`), and NOT (`~`) for conditional statements and filtering data.

- For instance, `x = 5; y = 3; result = (x > y); ` will assign the logical value `1` (true) to `result` because `x` is greater than `y`.

8. Conditional Statements:

- MATLAB supports standard conditional statements like `if`, `else`, and `elseif` for decision-making in scripts and functions.

- You can use these to control the flow of your code based on specific conditions.

9. Function Handles:

- MATLAB allows you to create function handles using the `@` symbol, enabling you to define custom functions and use them in various contexts.

10. Plotting and Visualization:

- MATLAB provides functions for creating 2D and 3D plots, histograms, scatter plots, and more, allowing you to visualize data and results effectively.

METHODOLOGY:

- Initialization: The process starts with the authentication of the mobile node (MN) to the cluster head (CH) using a proximity-based authentication mechanism. Once authenticated, the CH initiates a network binding process on behalf of the MN.
- Network Binding: The CH initiates a network binding process on behalf of the MN by sending a registration message to the Home Agent (HA) of the MN.
- Registration: The CH sends a registration message to the home agent (HA) of the MN, informing it that the MN is now residing within its service area. The HA updates its database and sends a registration acknowledgment to the CH.
- CH Responsibility: As long as the CH can sense the MN, it is responsible for maintaining the MN's address reachable by using its own IP address as the MN address.
- Address Maintenance: As long as the CH can sense the MN, it is responsible for maintaining the MN's address reachable by using its own IP address as the MN address. The MN ID is used internally in a table maintained by the CH.
- De-registration: If the MN moves out of the CH's service area, the CH sends a de-registration message to the previous CH that handled the MN. The previous CH updates its list of MNs and sends a de-registration acknowledgment to the MN HA. The MN HA updates its database and deletes the previous CH from its records.
- Proximity-Based Clusters: The MNs are partitioned into proximity-based clusters, where each cluster is created based on proximity-based authentication.
- Hierarchical Proximity-Based Consolidation (HPC): The proposed mobility management scheme is referred to as HPC, which is a user-centric and scalable approach.
- Mobility Group Creation: The CH actively manages the network connectivity of its clients and creates mobility groups based on proximity-based clusters. Each cluster is created based on authentication and communication with associated access network nodes (AANs). This hierarchical proximity-based consolidation (HPC) scheme reduces the number of MNs to the number of vehicles or human users, depending on the level of hierarchy.
- Handover and Signaling Reduction: The HPC scheme significantly reduces the handover rate and signaling cost compared to previous group mobility schemes. The CH actively manages the network connectivity, reducing the time and signaling required for establishing mobility groups.

HIERARCHICAL PROXIMITY BASED CONSOLIDATION

The effectiveness of High-Performance Computing (HPC) in reducing handover rates within cellular networks hinges on two critical factors:

1. Cell Size Ratio: This parameter relates to the ratio of the cell size of the Aerial Access Network (AAN), which the Cluster Head (CH) communicates with, to the average cell size within the area where the CH is currently moving.

2. Average Cluster Size: This factor refers to the average number of Mobile Nodes (MNs) that a CH manages within a cluster.

In anticipation of shrinking cell sizes in 5G and future networks, the potential benefits of utilizing AANs with larger service areas and cell sizes to support highly mobile devices become highly significant.

Furthermore, when considering the use of a vehicle-installed device as a "mini" nomadic Base Station (BS) within the HPC framework, additional equipment must be taken into account. HPC is proximity-based, creating a tradeoff between cluster size and proximity requirements. This tradeoff is inherent to the cellular structure of HPC, where a large AAN cell accommodates many mobile clusters. In situations where congestion arises, both existing cellular networks and HPC address this by splitting congested cells. As AANs complement terrestrial cellular networks to accommodate a larger number of highly mobile nodes in denser networks, additional equipment such as vehicle-installed CH devices is necessary for accessing the AAN.

In this section, we analyze the HPC scheme and compare it to other mobility management schemes, including DMM and previous NEMO-based methods. We assess these schemes from various perspectives, including practicality, scalability, radio signaling cost associated with mobility, privacy and security, and packet loss ratio.

HPC clusters are formed through short-range communication (e.g., Bluetooth) between the CH and its cluster members. Consequently, only the CH entity is exposed to the network, allowing for integration with network-based mobility management schemes like DMM. In this context, the CH can execute network-based strategies on behalf of itself and its cluster members. Therefore, the performance of the HPC scheme should be at least as good as DMM or any other network-based approach. However, due to the consolidation of cluster members, it's crucial to reduce the HPC signaling cost associated with mobility over the wireless link compared to these schemes.

RESULTS:

Here we have compared our proposed HPC scheme to DMM and GMM which are also Mobility Management Schemes that can be integrated with HPC for better performance.

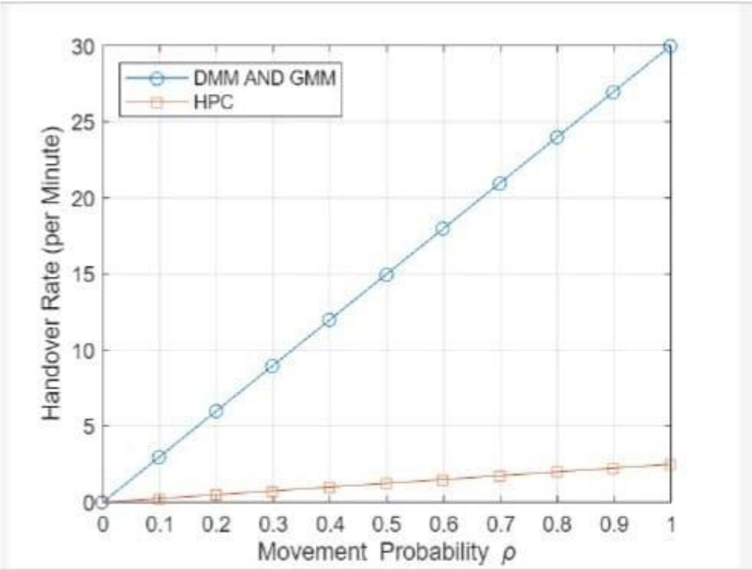

Fig 1: Comparision between HPC and GMM, DMM w.r.t. movement Probability

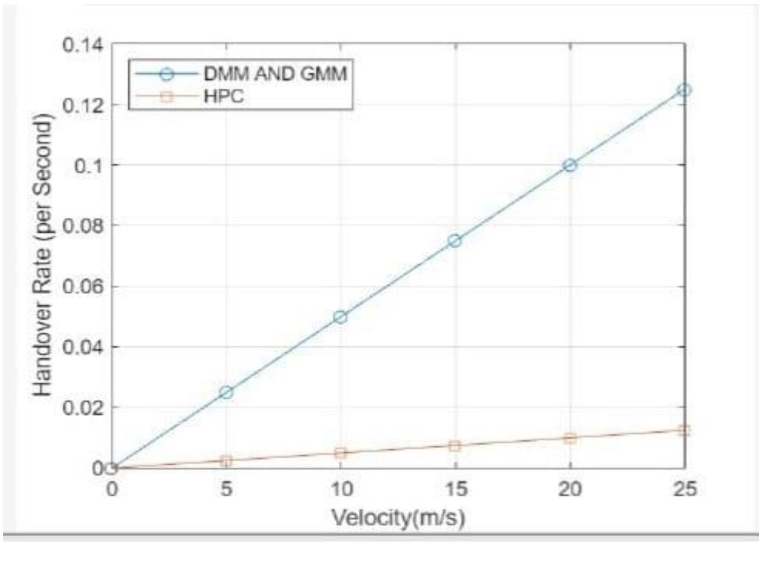

Fig 2: Comparision between HPC and GMM, DMM w.r.t. Velocity

DMM refers to Distributed Mobility Management whereas GMM refers to Gaussian Mixture Model .The performance Metrics that are considered here are Handover Rate per minute with respect to Movement Probability and Velocity.

CONCLUSION:

This work puts forth a solution to manage mobility in dense cellular networks, with a special focus on situations where devices move around rapidly. This is a significant challenge in such networks, and the paper suggests a novel approach to tackle it.The proposed scheme suggests the use of clusters based on device proximity. These clusters function as mobile cells and are integrated with Aerial Access Networks (AANs). The main objective is to reduce the problems caused by frequent handover requests in highly mobile scenarios, especially when a large number of devices are involved.One key feature of this scheme is its scalability. It can efficiently handle a growing number of devices while addressing practical, security, and privacy concerns.Compared to previous methods that use group-based approaches, this scheme outperforms them in terms of efficiency and support for real-time services. It achieves this by lowering the rate of handover requests and the signaling load on the Physical Random Access Channel (PRACH).To organize mobile nodes, the scheme employs a two-level hierarchical partitioning. Each cluster is managed by a designated cluster head (CH), which acts like a server. The CH is responsible for providing network services and managing the mobility of the mobile nodes within its cluster.Simulation results showcased the effectiveness of this proposed scheme. It demonstrated a significant reduction in the frequency of handover events, even when dealing with different mobility patterns, such as random motion and directional movement. Importantly, this scheme is versatile and can be applied to 5G and future networks, making it capable of supporting a large number of Internet of Things (IoT) devices while ensuring seamless access with Quality of Service (QoS) guarantees.In summary, the mobility management scheme proposed in this paper offers an efficient solution for dealing with high mobility scenarios in densely populated cellular networks. It effectively addresses the challenges of frequent handover requests and supports a large number of rapidly moving devices. Its scalability, support for real-time services, and performance advantages make it a promising approach for future network deployments.

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