

DML Assignment – 1 (Part-3)

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Part 3: Industry-Oriented Analysis (30 Points)

1) Based on your partitioning experiments:

a) Recommend scenarios where vertical partitioning is more effective:

Vertical partitioning involves dividing the database or data set into smaller subsets based on attributes or columns. This approach is particularly effective in scenarios where different subsets of data are used frequently by different applications, and optimizing data access is a priority.

EFFECTIVE SCENARIOS FOR VERTICAL PARTITIONING:

- 1) **Data Warehousing and Analytics:** Vertical partitioning is useful in situations where large-scale analytical queries are run. In 5G networks, data can be partitioned by attributes like traffic type (e.g., eMBB, URLLC, massive IoT) or resource utilization. Vertical partitioning helps improve query performance for specific columns needed in analytics, reducing data transfer overhead.
- 2) **Resource Allocation in 5G Networks:** In resource allocation tasks, vertical partitioning can help when specific resources (e.g., spectrum allocation, energy consumption, or bandwidth) are only needed by particular services like autonomous vehicles or IoT. Each partition can then focus on a specific attribute, optimizing resource access for certain applications.
- 3) **Real-time Traffic Management:** If traffic management relies on specific features (e.g., traffic load, latency, and reliability), vertical partitioning is beneficial. It allows for more targeted data retrieval based on key traffic metrics that are frequently analyzed for quick decision-making.

b) Suggest situations better suited for horizontal partitioning:

Horizontal partitioning divides data into smaller subsets based on rows or records. This is effective when there are large datasets with similar structure but different records, and the query load is distributed evenly across different partitions.

EFFECTIVE SCENARIOS FOR HORIZONTAL PARTITIONING:

- 1) **Geographically Distributed Data:** In the case of 5G networks, horizontal partitioning works well for data that is geographically distributed, such as user data and network traffic logs across multiple regions or network nodes. Each partition can hold data for a specific region or zone, enabling more efficient and localized processing.
- 2) **Massive IoT Deployments:** In massive IoT (mIoT) scenarios, where billions of devices are involved, horizontal partitioning can separate data generated from different devices or sensor clusters. This partitioning method allows for scalable storage and retrieval of time-series data or event-based information across different device groups.
- 3) **User-Level Data Segmentation:** For use cases such as network slicing or personalized service delivery, horizontal partitioning can be used to store user-specific data (e.g., data for autonomous vehicles or mobile users). This ensures that each partition contains a manageable subset of user data and helps with load balancing across the network.

2) Prepare a concise report or presentation for a potential Qualcomm use case:

a) How can these techniques improve scalability and performance in 5G network optimization?

Model and Data Partitioning enhance scalability and performance in 5G network optimization by distributing computational loads across edge and cloud servers, enabling real-time traffic prediction and resource allocation. These techniques reduce latency, improve bandwidth efficiency, and accelerate AI-driven decision-making for dynamic network management.

SCALABILITY:

1. **Vertical Partitioning:** By dividing data into smaller, manageable partitions based on features, vertical partitioning improves the ability to scale the system across different network functions (e.g., eMBB, URLLC, massive IoT). It enables the network to handle large volumes of specific data types (such as traffic patterns, energy consumption metrics, etc.), supporting quick access to relevant data for different network slices.
2. **Horizontal Partitioning:** This approach improves scalability in distributed systems like 5G networks, especially when user traffic and devices are geographically dispersed. It ensures that network infrastructure doesn't become overloaded by partitioning the data by user or region. This is essential for handling the high volume of data generated by devices in autonomous vehicle networks or smart cities.

PERFORMANCE:

1. **Vertical Partitioning:** Reduces the query time and overhead by focusing on only the necessary data columns. In 5G, where real-time resource allocation is crucial, partitioning data by service type or traffic type allows for more efficient and targeted network optimization. AI models used in resource allocation can retrieve only relevant data without unnecessary computations, enhancing the responsiveness of the system.
2. **Horizontal Partitioning:** Helps to manage large datasets and maintain low latency by dividing data horizontally across different regions. Each partition can be optimized independently, leading to faster processing and analysis. For example, network slicing can be optimized more efficiently by partitioning network traffic and resources based on geographical regions or user demands.

b) What challenges might arise in deployment, and how would you address them?

CHALLENGES IN DEPLOYMENT:

1. **Data Partitioning Overhead:** Both vertical and horizontal partitioning can introduce overhead in terms of managing the partitions, particularly when dealing with dynamic, real-time data from 5G networks. Data must be continuously split and redistributed as network demands change, which can cause delays if not handled efficiently.
2. **Latency and Real-time Optimization:** Vertical partitioning can potentially cause latency issues if complex queries span multiple partitions. Similarly, horizontal partitioning might lead to inconsistent performance when a specific region experiences high traffic or load.
3. **Coordination in Multi-Agent Systems:** In 5G network optimization, especially when using multi-agent reinforcement learning (MARL) for resource allocation, coordinating the agents that manage different partitions can be challenging. Ensuring that the agents share relevant information and don't conflict in their actions is essential for smooth operation.

ADDRESSING CHALLENGES:

1. **Use Federated Learning or Edge Computing:** To mitigate data partitioning overhead and reduce latency, deploying federated learning or edge computing can help distribute the computational load closer to the network edge. This reduces the need for constant data transfer and speeds up real-time decision-making processes.
2. **Dynamic Load Balancing:** Employ dynamic load balancing algorithms to ensure that partitions are balanced according to traffic demands. This ensures that regions with high demand (e.g., urban areas) can have more resources allocated without overwhelming the system, while areas with less traffic can reduce their data load.
3. **Hybrid AI Models:** To address coordination issues in MARL systems, hybrid AI models combining reinforcement learning with supervised or unsupervised learning can help optimize decision-making and resource allocation. These models can learn from different data sources and adapt to new conditions, improving both performance and scalability.

CONCLUSION

Implementing horizontal and vertical partitioning in 5G network optimization plays a crucial role in enhancing scalability and performance by enabling efficient resource allocation and traffic management across distributed network components. Horizontal partitioning (dividing data by samples) is beneficial for balancing network traffic loads, while vertical partitioning (splitting by features) ensures optimized feature-based processing in AI-driven models. To maximize effectiveness, it is essential to address key challenges such as data synchronization, partitioning overhead, latency reduction, and coordination between distributed nodes. Utilizing advanced AI techniques like federated learning, dynamic load balancing, and edge-cloud collaboration can further streamline partitioning, ensuring seamless deployment. By incorporating these strategies, Qualcomm and other industry leaders can drive innovation in next-generation 5G infrastructure, enabling faster, more adaptive, and intelligent network management.