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|  | **Project Assignment for the Course on**  **Fog and Cloud Computing**  **Autumn 2024/2025**  **IFI/UiO** |
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**Group Project Report**

Group: \_3\_

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# Introduction

**Basic Modules**:

* CanNode: Represents garbage cans equipped with sensors to monitor fill levels.
* CloudNode: Represents a centralized cloud server that collects and processes data from garbage cans and trucks.
* Host: Represents a general-purpose communication device that can transmit data between garbage cans and the cloud.
* TruckHost: A specific type of host that represents garbage trucks responsible for collecting garbage based on the data received from cans and the cloud.

**Types**:

* TurtleMobility: These modules are used for representing the mobility of the TruckHost.
* IntegratedVisualizer: Provides a graphical representation of the system during simulation, visualizing the interactions between the nodes.
* PhysicalEnvironment: Defines the physical simulation space where the garbage collection activities take place.

# Simulation Settings

The simulation considers different **data rates** and **delay values** to represent the communication between the modules in the system. These values are configured to simulate real-world scenarios of data transmission speeds and latencies:

* **Data Rates** (assumed):
  + Cloud communication data rate: 1 Gbps.
  + Host-to-cloud communication: 500 Mbps.
  + Can-to-host communication: 100 Mbps.
* **Delay Values**:
  + Communication between CanNode and CloudNode: 100ms delay.
  + Communication between CanNode and TruckHost: 100ms delay.
  + Communication between TruckHost and CloudNode: 200ms delay.
* **Rationale:**
  + **Fast Messages (100ms)**: This delay simulates a reasonably quick communication scenario, such as local area network (LAN) communications. For example, in environments where devices are closely connected (like IoT devices in smart cities), a 100ms delay reflects the time it might take for data packets to be sent and acknowledged without significant congestion.
  + **Slow Messages (200ms)**: This delay represents situations where communications occur over longer distances or through more congested networks, such as wide area networks (WAN) or the Internet. It accounts for the additional time required for data to traverse greater distances and for potential queuing in the network.

These delay values reflect the network latency in various communication pathways, with the highest latency for the communication between trucks and the cloud, representing real-world network conditions.

# Comparison of all Solutions (Cloud, Fog, and No garbage)

This section provides a comparison between the different configurations of the system, focusing on **Cloud-based**, **Fog-based**, and **No Garbage** solutions.

## Number of Messages Exchanged

* **Cloud Solution**: In the cloud solution, messages are first passed to TruckHost before forwarding them to the CloudNode. This results in a high number of messages exchanged due to the centralized nature of communication.
* **Fog Solution**: In the fog-based solution, CanNode directly send messages to CloudNode, reducing the number of exchanges between TruckHost and CloudNode and, consequently, the total number of messages exchanged.
* **No Garbage Solution**: This scenario serves as a baseline for comparison, where no data exchanges occur between TruckHost or CanNode and the CloudNode. This setup highlights the overhead introduced by the communication layers in the other solutions.

## Delay Spent When Sending Messages

* **Cloud Solution**: The delay for sending messages is higher in this scenario, primarily due to the additional latency between the CanNode and CloudNode, as well as between TruckHost and CloudNode (200ms). This delay is significant for time-sensitive operations like routing optimization.
* **Fog Solution**: The sending delay is reduced due to the local processing by TruckHost, which minimizes the reliance on long-distance communication with the cloud.
* **No Garbage Solution**: As there are no active communications between TruckHost or CanNode and CloudNode, the delay in message sending is effectively zero, providing a benchmark for measuring the delay overhead introduced by other setups.

## Delay Spent When Receiving Messages

* **Cloud Solution**: The time to receive messages is also greater here due to the cloud’s role as an intermediary in every data exchange.
* **Fog Solution**: Similar to message sending, the receiving delay is reduced as TruckHost nodes handle part of the processing locally, leading to quicker responses.
* **No Garbage Solution**: With no data exchanges between TruckHost or CanNode and CloudNode, the delay in receiving messages will be minimal.

# Improvement

To enhance the efficiency of the Garbage Collection System, several potential improvements can be considered:

* **Edge Processing**: Implementing more edge-based processing at TruckHost nodes could further reduce the latency by minimizing the interactions with the cloud.
* **Adaptive Communication**: Dynamically adjusting the data rates based on network load could optimize the bandwidth usage and reduce the congestion during peak hours.
* **Message Aggregation**: By aggregating multiple sensor data points before transmission, the overall number of messages exchanged could be reduced, leading to decreased network traffic and latency.

# Videos

Links to the videos that showcase the simulation of each solution:

* **Cloud Solution Video**: <https://youtu.be/YbPabDxmCno>
* **Fog Solution Video**: <https://youtu.be/-Mh93rIzXLc>
* **No Garbage Solution Video**: <https://youtu.be/UdWfHMJj62s>

These videos demonstrate the communication and interactions between different modules in the simulated scenarios.

# Observations

In this section, I would like to share some observations made during the development and simulation of the Garbage Collection System:

* **Scalability Considerations**: The cloud-based approach becomes less efficient as the number of nodes increases due to the centralized nature of data processing. A hybrid approach involving both cloud and edge processing offers better scalability.
* **Network Latency Impact**: The delay introduced in message exchanges between modules significantly impacts the overall system performance. Minimizing the communication with the cloud improves responsiveness, especially for real-time decision-making in garbage collection.
* **Real-World Applicability**: This simulation demonstrates the potential of smart waste management systems, providing insights into how different architectures can affect performance. It highlights the trade-offs between centralized processing (cloud) and distributed processing (fog/edge).