Preparedness for managing pandemic using distributed mobile brokers – Using COVID 19 use case

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ABSTRACT

The human community has experienced the worst disaster during this pandemic spread of COVID-19. Getting essential services viz., medical, food, water, and oxygen support have been challenging during the pandemic. People suffer inadequate essential services during these lockdowns and quarantines. This paper proposes a distributed mobile broker service using the MQTT protocol for managing and accessing essential services during a pandemic. The proposed method splits the city into areas. The essential service providers register their services with the publishers and the essential service seekers seek their services from the publishers using mobile brokers. The mobile broker is also equipped with data aware trajectory planning technique that considers collecting data from available nodes with less delay. The proposed technique has been tested under two scenarios viz., mobile brokers, fixed subscribers, and mobile brokers, mobile subscribers. The performance analysis has been carried out in terms of delay and packet delivery ratio with fixed broker conditions.

1. Introduction

Pandemics are sudden outburst of infectious diseases throughout the world that changes the economic, social, and human culture [1]. Many infectious diseases viz., cholera, flu, tuberculosis, measles have had their worst spread in human history. In 2019, coronavirus (COIVD-19), a deadly disease that originated from Wuhan, china cause severe motility across the globe. Nearly with 113 million affected and 2.5 million of mortality, the novel coronavirus still has its spread across 219 countries [2]. This virus has severe respiratory concerns with fever and pneumonia. In such a wild spread of pandemics, people need various essential services viz., food, oxygen support, medical support. News and media are portraying continuously the result of people suffering without getting such essentials on time. This paper proposes a distributed mobile publish/subscribe environment using mobile brokers in Message Queuing Telemetry Transport (MQTT) protocol. Considering COVID-19 as a use case, the proposed technique has been

tested in a simulation environment. From the test result, it is evident that the distributed mobile brokers are a soul saver during such pandemic situations (see Fig. 1).

Section 2 reviews various papers related to MQTT and its variants. Section 3 explains the proposed distributed mobile broker environment. Section 4 explains the implementation and result analysis. Section 5 concludes the session with future research scope.

2. Related works

Various literature has explored the functioning of the MQTT protocol. This section reviews various proposals in MQTT, distributed MQTT, and mobile MQTT.

2.1. Message Queuing Telemetry Transport (MQTT)

MQTT is a lightweight protocol for sending messages in a connected environment [3]. It provides ordered, lossless, & bi-directional connections. The MQTT protocol comprises three key elements: subscriber, publisher, and a broker. It proves to be a better choice for wireless networks that experience occasional

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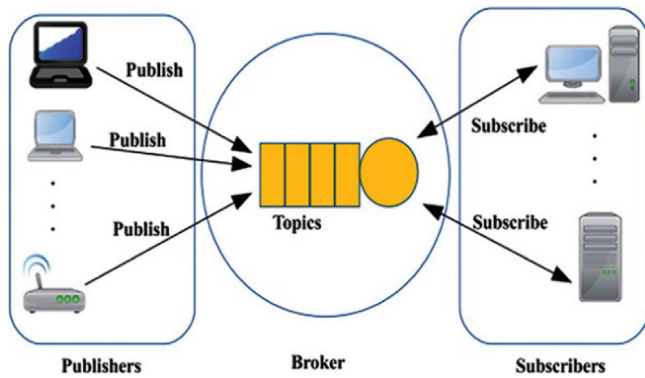*E-mail address:* getzi@karunya.edu (G.J.L. Paulraj).

Fig. 1. Components of MQTT Protocol.

bandwidth constraints or unreliable connections. For instance, Facebook is using MQTT in Facebook Messenger for online chat.

The Publisher in the environment publishes the collected data to the message brokers. The subscribers subscribe to the topics. The role of the broker is to communicate the suitable topic's information to the appropriate subscriber. However, having a single broker suffers from a single point of failure, traffic volume, hotspot problem, and maintenance [4].

2.2. Distributed brokers

To overcome the drawbacks of a single broker in the MQTT environment, various researchers have explored distributed broker environments.

In [5], the authors propose a load balancing protocol for distributed broker environment. The proposed system has been tested using Amazon web services and local machines. The comparative results have been evaluated for several messages received and transmitted by each broker at a given time. A spanning tree protocol has been introduced to regularize redundancy in distributed broker environments in [6]. In-band signaling is used by the protocol allowing full message replication and robustness against failures in the brokers. To distribute messages among them, MQTT brokers are interconnected in a loop-free topology. This protocol has been tested in various experimental scenarios keeping in mind the components such as latency, computational load, and throughput, and compared with traditional cloud-based and Single-broker systems. In [7], Internetworking for distributed architecture has been proposed. Two algorithms namely Publication Flooding (PF) and Subscription Flooding (SF) have been proposed to check the feasibility and versatility of its Internetworking API. A benchmark system for single and multiple brokers has been introduced to evaluate the effectiveness of the proposed technique. The proposed system is evaluated with a Mosquito broker and proves to be five times better.

A virtual ring approach for a distributed broker has been proposed in [8]. MQTT is adopted as an endpoint and internetworking point protocol. Experiments on the brokers are done using Queuing Analysis. Flooding Approach and Virtual Ring Approach are used to analyze the performance of the architecture and then concluded that Virtual Ring Approach is better than Flooding Approach based on Queuing Analysis. Three distributed brokers implemented using the Goal/Question/Metric scheme have been evaluated for scalability, performance, security, resilience, usability, and extensibility in [9]. Decision guidance for MQTT brokers specifying six decision points has been propounded. Performance, Scalability, Average Message Loss during Resilience Test, and Security are evaluated to evaluate the performance of the brokers. The best performance was seen in EMQX but no loss of message was seen in HiveMQ. VerneMQ is an open-source showing similar qualities as commercial brokers. A similar distributed broker environment has been

proposed in [10 11]. However, in all these approaches the broker is considered to be static. Such static brokers lead to the following limitations:

- Quick access is provided to near subscribers than distant subscribers.
- Service can be provided only locally to the broker.
- Data collection depends on extra relay nodes in a distributed location such as smart cities and agriculture.

Hence there is a need for mobile broker that collects data from the publishers anywhere and anytime. In addition the operation of mobile brokers have been enhanced with data aware trajectectory planning technique for collecting data from the available nodes on priority basis. This enable quick collection of data from the needed place and improve the service of MQTT protocol.

3. Distributed mobile brokers for handling COVID-19 pandemic situations

During this pandemic, people suffered to get some essential services viz., food, water, oxygen support, and medical facilities due to strict lockdowns and quarantines. This has motivated to propose a distributed mobile broker to get the essential services to the human community.

The proposed distributed mobile brokers are depicted in Fig. 2. Every geographical location is split into hexagonal-shaped areas. Every area contains service providers, subscribers, publishers, and a mobile broker.

- **Service Providers:**
  - The service provider registers the available services with the nearby publishers. It also updates their service availability on a timely basis.
- **Publishers**
  - The publishers publish the data with the mobile area brokers as they approach the publishers.
- **Mobile area brokers**
  - Mobile area brokers collect the data from publishers and make it available to the subscribers. Every area has one mobile broker that collects data from the publishers and made it available to the subscribers. The mobile brokers also deliver the data to the nearby located mobile brokers to make it available for the nearby area subscribers.
- **Subscribers**
  - The subscribers collect the relevant data through the mobile area brokers.

The mobile broker is enabled with data aware data collection trajectory planning module for efficiently collecting data from the publishers.

Initially, the publishers communicates the amount and priority of the data to the broker. The priority is set based on the demand of the data. Based on the communicated value the broker assigns weight W_L to the publishers. The data collection zones are fixed using weighted maximum vertex cover algorithm [12] shown below.

Algorithm: weighted minimum vertex cover

Step1 : Let n, be the number of nodes.
Step 2 : cluster_sort = sort(V_i (W)) ; V_i denotes the publisher node and W correspons to the weight assigned based on data.
Step 3 : path = select {max (cluster_sort)}
Step 4 : Let V_i and V_j be neighbors of cluster_sort(i).
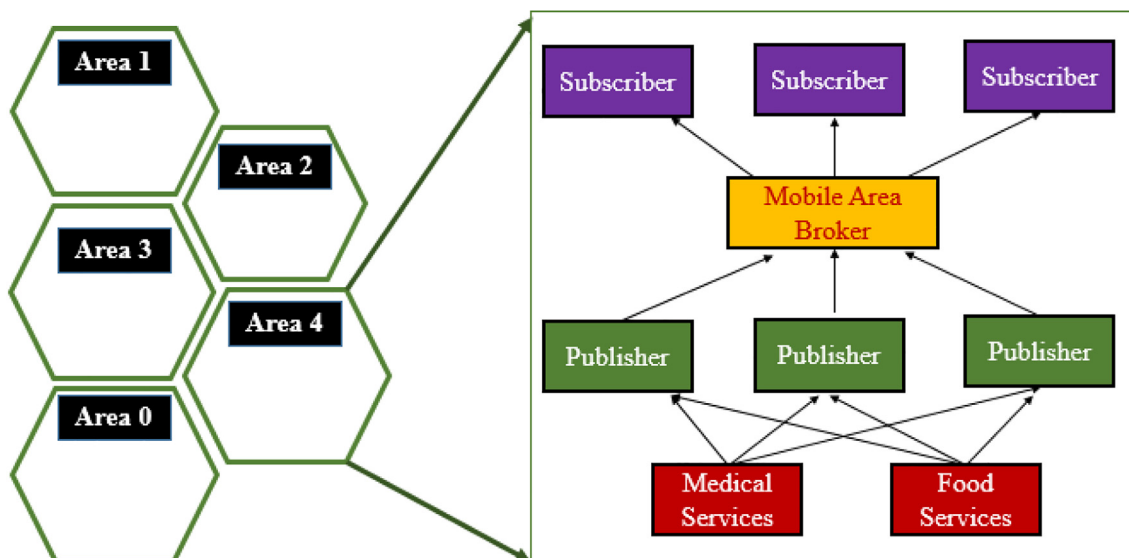*path = del (V_i,V_j)*
Step 5 : Repeat Step 3

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Fig. 2. The architecture of Distributed Mobile Broker.

Table 1
Simulation parameters.

S. No	Entity	Number
1	Number of Areas	4
2	Number of Subscriber node	200 nodes
3	Mobile broker	2–4
4	Number of Publisher node	4
5	Number of service providers	3
6	Mobility pattern - Mobile broker	Random waypoint model
7	Mobility pattern - Subscribers	Random waypoint model
8	Speed of mobile brokers	20 m/s, 40 m/s, 60 m/s, 80 m/s and 100 m/s
9	Sensing Field topography	200×200 m^2

The broker selectively chose the zone for data collection, position itself and collect data from the nearby nodes. In this method publishers with huge and important data is collected.

4. Implementation and result analysis

The proposed technique has been simulated using NS-2.35. The simulation parameters are displayed in the Table.1

The performance metrics viz., delay and packet delivery ratio have been obtained and evaluated under the following conditions:

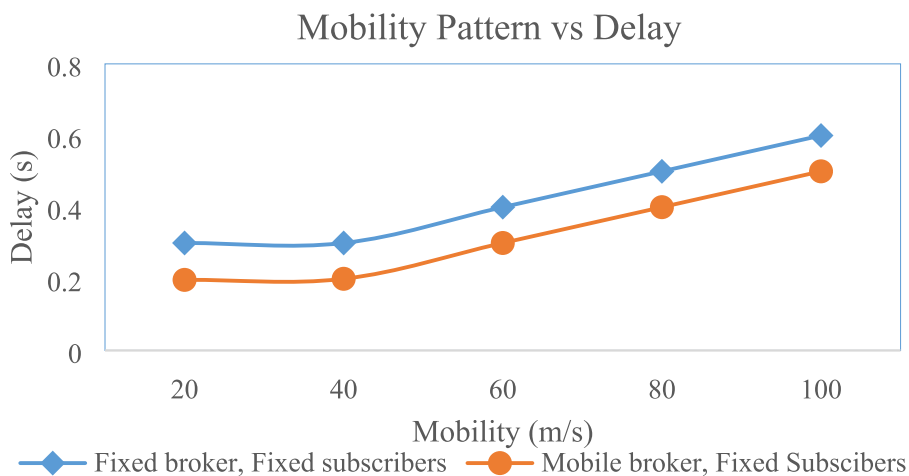- Scenario − 1: Mobile broker, Fixed subscribers vs Fixed broker, Fixed subscribers

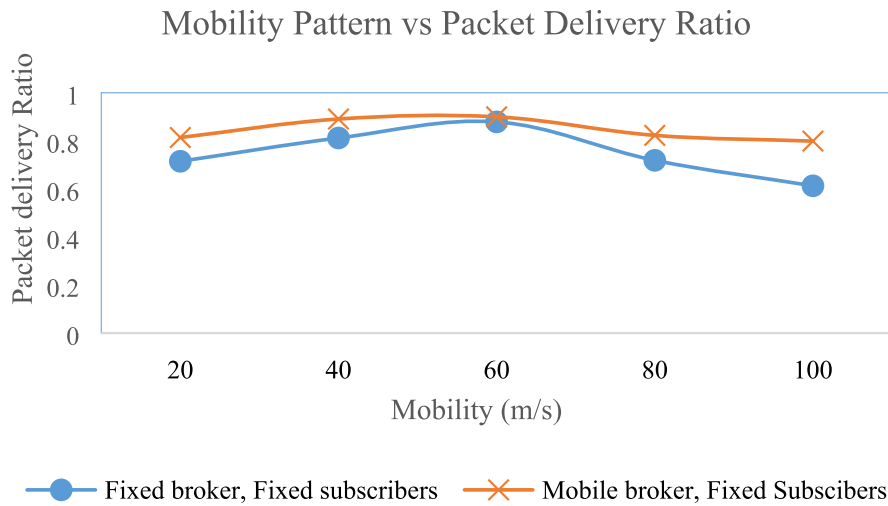**Fig. 3.** Delay in secs for scenario 1.

Mobility Pattern vs Packet Delivery Ratio

Fig. 4. Packet delivery ratio for scenario 1.
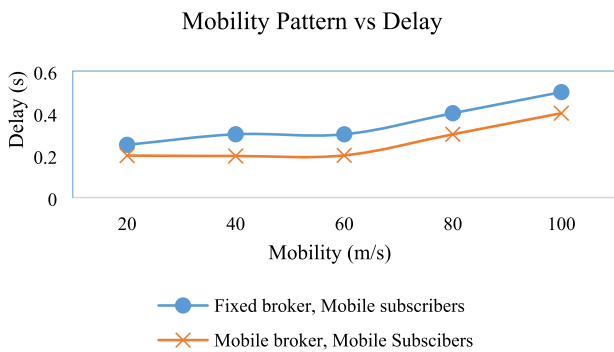
Mobility Pattern vs Delay

Fig. 5. Delay in secs for scenario 2.

- Scenario − 2: Mobile broker, Mobile subscribers vs Fixed broker, Mobile subscribers

Delay is the total time required for the service message to reach the intended subscribers. Packet delivery ratio is the ratio of the total message delivered to that of the total message transmitted.

Fig. 3 displays the delay calculation for scenario − 1 by varying the mobility of the mobile brokers from 20 m/s to 100 m/s by varying in 20 steps. From the figures, it is evident that delay is considerably reduced for mobile brokers compared to that of fixed brokers. However, the delay increases after the speed of the mobile broker increase after 80 m/s speed. However, it is found that the delay increases gradually as the mobility crosses 80 m/s

Fig. 4 shows the packet delivery ratio of the scenario − 1. It is found that the packet delivery ratio is appreciably good when the mobility is between 20 m/s and 60 m/s. After 60 m/s, the packet delivery ratio reduces. Similar simulation is also performed using scenario − 2, Mobile broker, Mobile subscribers vs fixed broker, Mobile subscribers.

Fig. 5 Shows the delay calculation for scenario − 2 by varying the mobility from 20 m/s to 100 m/s. From the figure, it is depicted that, the delay decreases till the mobility is around 60 m/s. As the mobility increases for both broker and subscribers, the delay also increases.

Fig. 6 shows that the packet delivery ratio is high when the mobility is between 20 m/s and 60 m/s. However, when the mobility increases for both the broker and subscribers, there is slight depletion in the packet delivery ratio. From the analysis results, it is clear that improvised mobility has to be introduced to
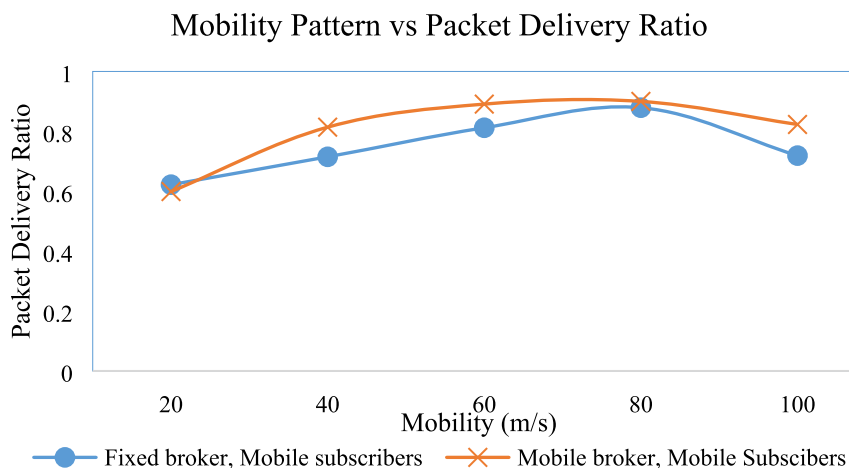
Mobility Pattern vs Packet Delivery Ratio

Fig. 6. Packet delivery ratio for scenario 2.

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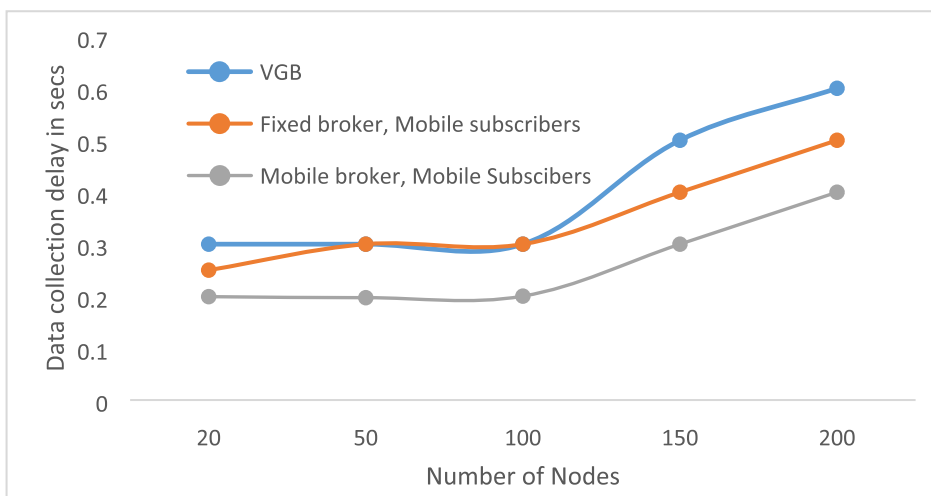Materials Today: Proceedings 51 (2022) 2384–2388

Fig. 7. Data acquisition latency by increasing number of nodes.

regularise the data delivery between the broker and the subscribers which can be dealt with as future work.

4.1. Performance analysis on data acquisition latency

The data aware trajectory planning technique has been compared with virtual grid based (VGB) data collection proposed in [13]. Data acquisistion latency is measured as the time taken by the mobile borker to collect the available data from all the nodes. The nodes are increased as 50, 100, 150 and 200.

From Fig. 7 it is understood that the VGB technique has consider data collection only at the grid points. However, proposed technique has considered collected data based on the availability with the broker using vertex cover algorithm. This offers optimized data collection on the required points thereby reducing the data collection delay.

5. Conclusion

A distributed mobile broker for the publish-subscribe system has been proposed. This system can be used to access essential services during pandemic situations. Since the brokers are mobile people will be able to access the service in the place where they are available. The proposed system has been tested using a simulation environment evaluating the delay and packet delivery ratio. The technique is also proposed using two scenarios with the mobile broker, fixed subscribers, and mobile broker, mobile subscribers against the fixed broker, subscriber system. The mobile broker technique shows improved performance analysis compared with the fixed broker system. The proposed technique can be improvised by defining mobility patterns for mobile brokers.

CRediT authorship contribution statement

Snowlin Preethi Janani: Conceptualization. **Immanuel John-Raja Jebadurai:** Project administration. **Getzi Jeba Leelipushpam Paulraj:** Methodology. **Jebaveerasingh Jebadurai:** Writing - review and editing. **S. Durga:** Software.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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