Spatial Internet of Things

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Spatial Internet of Things

Overview of Presentation

- Introduction
- IoT Communication Protocols
- Publish/Subscribe Messaging Pattern
- Spatial Publish/Subscribe (SPS)
- Spatial Publish/Subscribe Use Cases
- Open-source Library – VAST.js
- Conclusions

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Internet of Things (IoT)

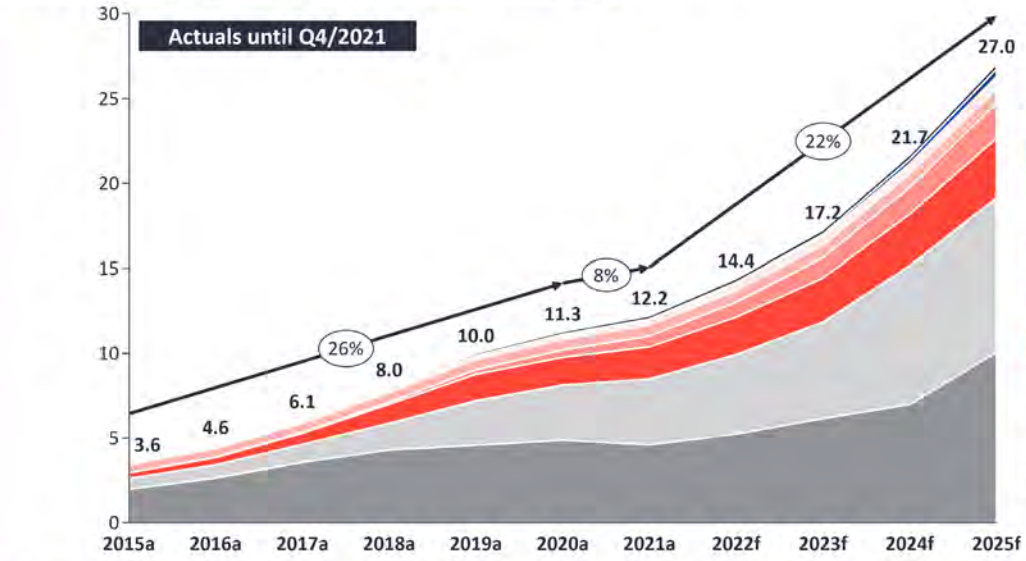
IOT ANALYTICS

May 2022

Your Global IoT Market Research Partner

Global IoT Market Forecast [in billion connected IoT devices]

Number of global active IoT Connections (installed base) in Bn



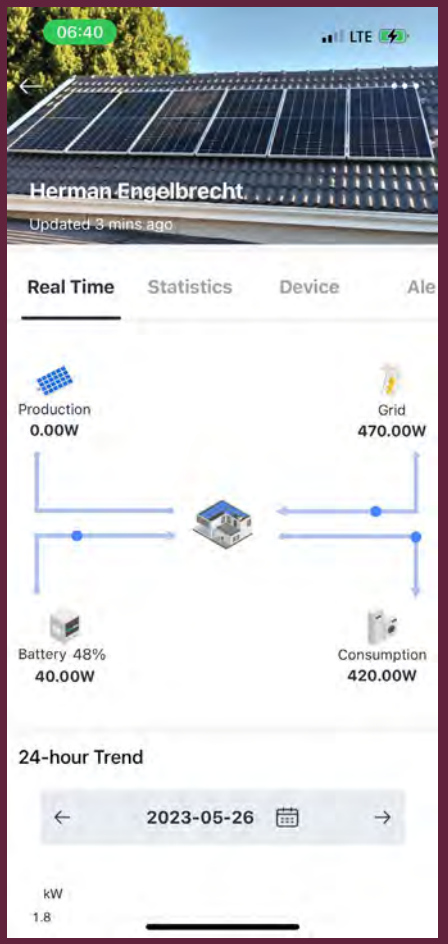
CONNECTIVITY TYPE	CAGR 20-21	CAGR 21-25
Wireless Neighborhood Area Networks (WNAN)	17%	11%
5G IoT	-	159%
Other	22%	20%
Wired IoT	4%	7%
LPWA	42%	34%
Legacy Cellular (2G/3G/4G)	16%	17%
Wireless Local Area Networks (WLAN)	19%	24%
Wireless Personal Area Networks (WPAN)	-6%	22%

XX% = CAGR

Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes Ethernet and Fieldbuses (e.g., connected industrial PLCs or I/O modules); Cellular includes 2G, 3G, 4G; LPWAN includes unlicensed and licensed low-power networks; WPAN includes Bluetooth, Zigbee, Z-Wave or similar; WLAN includes Wi-fi and related protocols; WNAN includes non-short range mesh, such as Wi-SUN; Other includes satellite and unclassified proprietary networks with any range.

Source: IoT Analytics Research 2022. We welcome republishing of images but ask for source citation with a link to the original post and company website.

Source: https://iot-analytics.com//number-connected-iot-devices



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Commonly used IoT Communication Protocols

AMQP
Advanced Message Queuing Protocol

MQTT

CoAP
RFC 7252

Stomp

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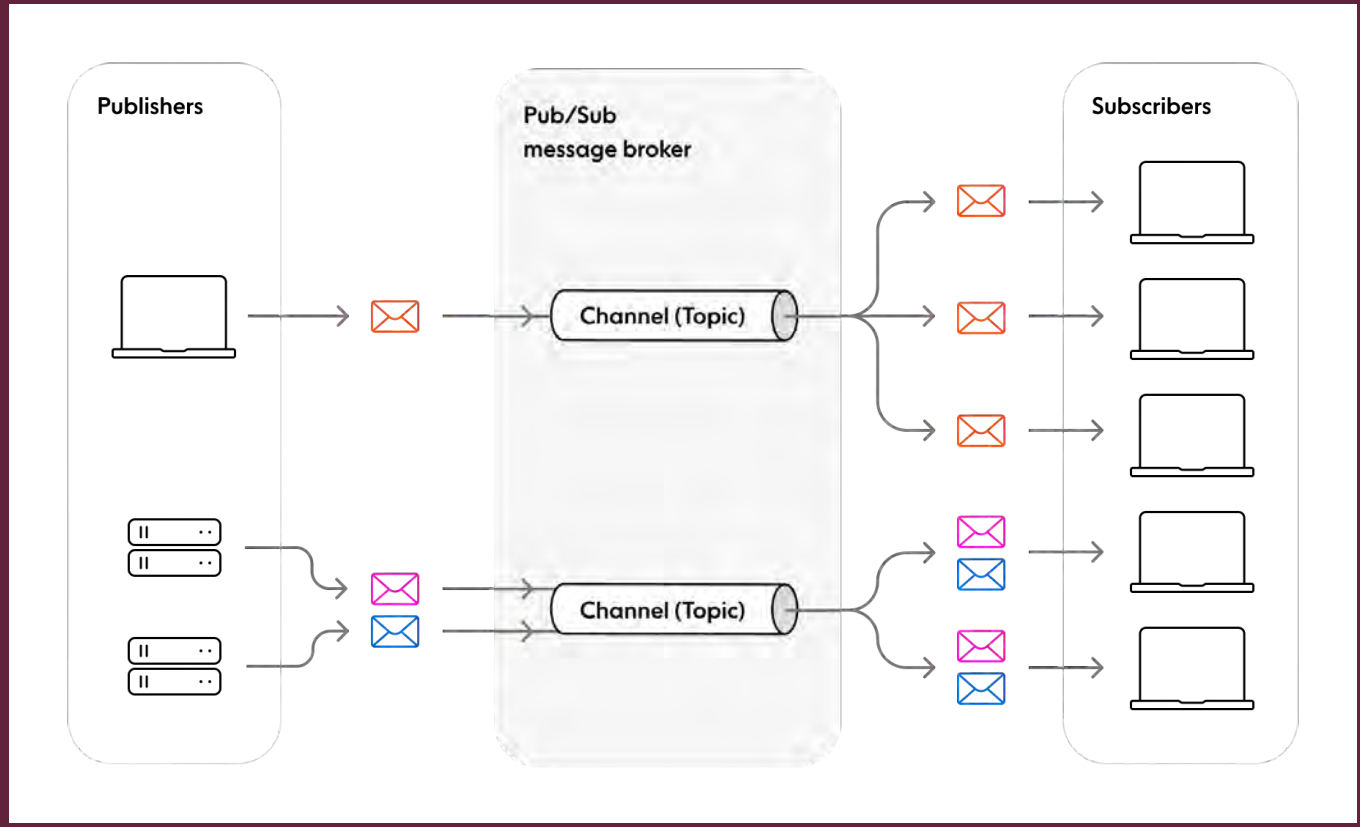
Publish/Subscribe Messaging Pattern

- Asynchronous communication
- Publishers do not send messages directly to subscribers
- Publishers pass messages through central message broker
- Improved scalability by decoupling publishers and subscribers and allowing brokers to route and duplicate messages



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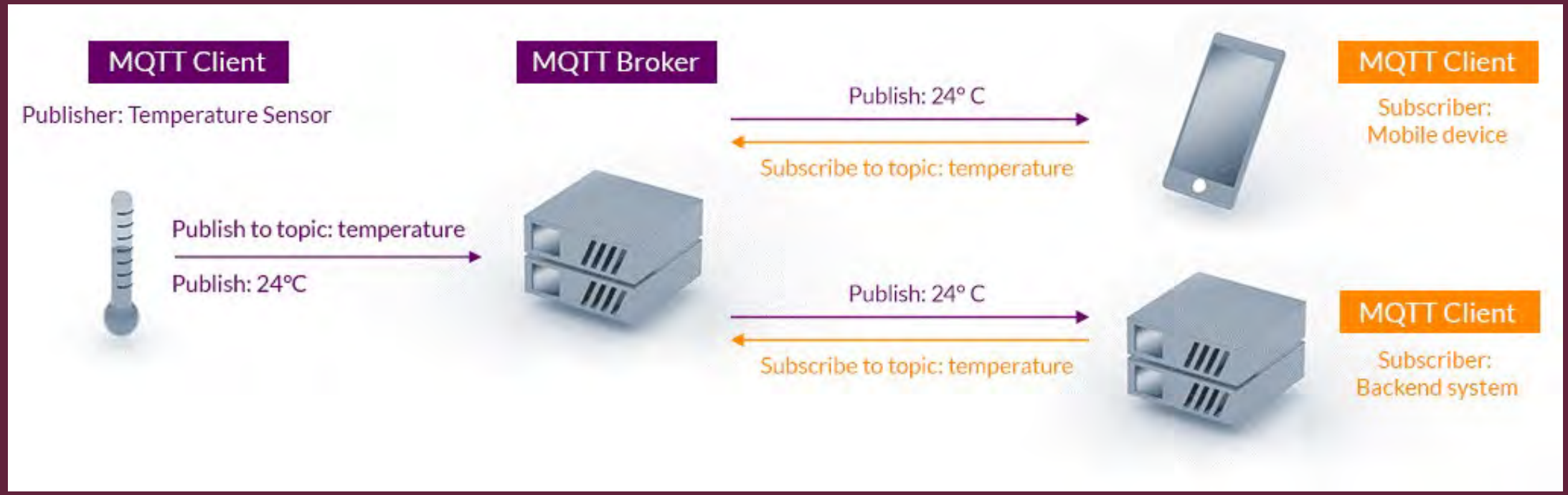
Topic-based Publish/Subscribe

- Publish/Subscribe based IoT protocols uses topics to transfer messages
- Clients publish messages to a specific text-based topic
- Clients subscribe to a set of **text-based topics**. Clients receive any messages published to those topics.
- Brokers filter messages by matching publication topics with subscribers
- Brokers route a publication to all clients subscribed to the publication's text-based topic
- Clients can simultaneously be publishers and subscribers

Publish/Subscribe using MQTT

Publications consists of **{publisher, topic, payload}**



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Limitations of Topic-based Publish/Subscribe

- Topic discovery by clients
- Limit expressiveness - a subscriber has to receive all messages even if the subscriber is only interested in a subset of messages
- Data related to IoT devices often contain location information
- Topic-based publish/subscribe not designed to efficiently handle location information

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Spatial Publish/Subscribe

- Spatial Publish/Subscribe (SPS) route messages based on location data
- **Spatial Publications consists of {publisher, location data, topic, payload}**
- **Clients publish messages to a specific area (as specified by location data)**
- **Clients subscribe to receive messages published in a specific area**
- Brokers filter messages by matching publication areas with subscription areas
- Brokers route a spatial publication to all clients whose subscription areas overlap with the publication area

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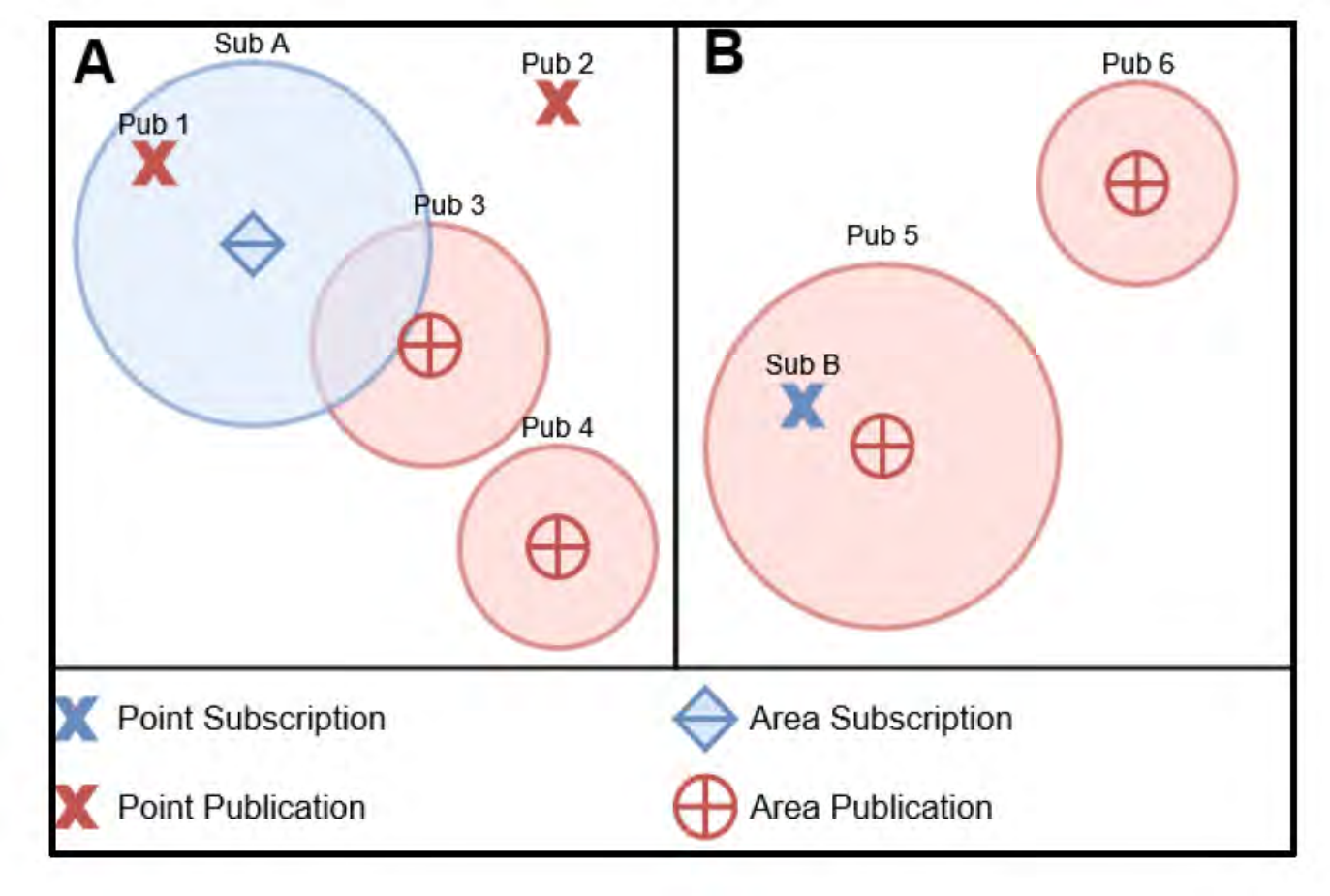
Spatial Publish/Subscribe



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Benefits of Spatial Publish/Subscribe

- IoT devices can publish data based on location data (and topic)
- Clients can change subscription area to only receive pertinent messages
- Brokers use location data to route messages from publisher to subscriber
- Decentralized configuration with multiple brokers that each manage the closest clients

BUT

- Message filtering is more complex
- Added overhead of location data

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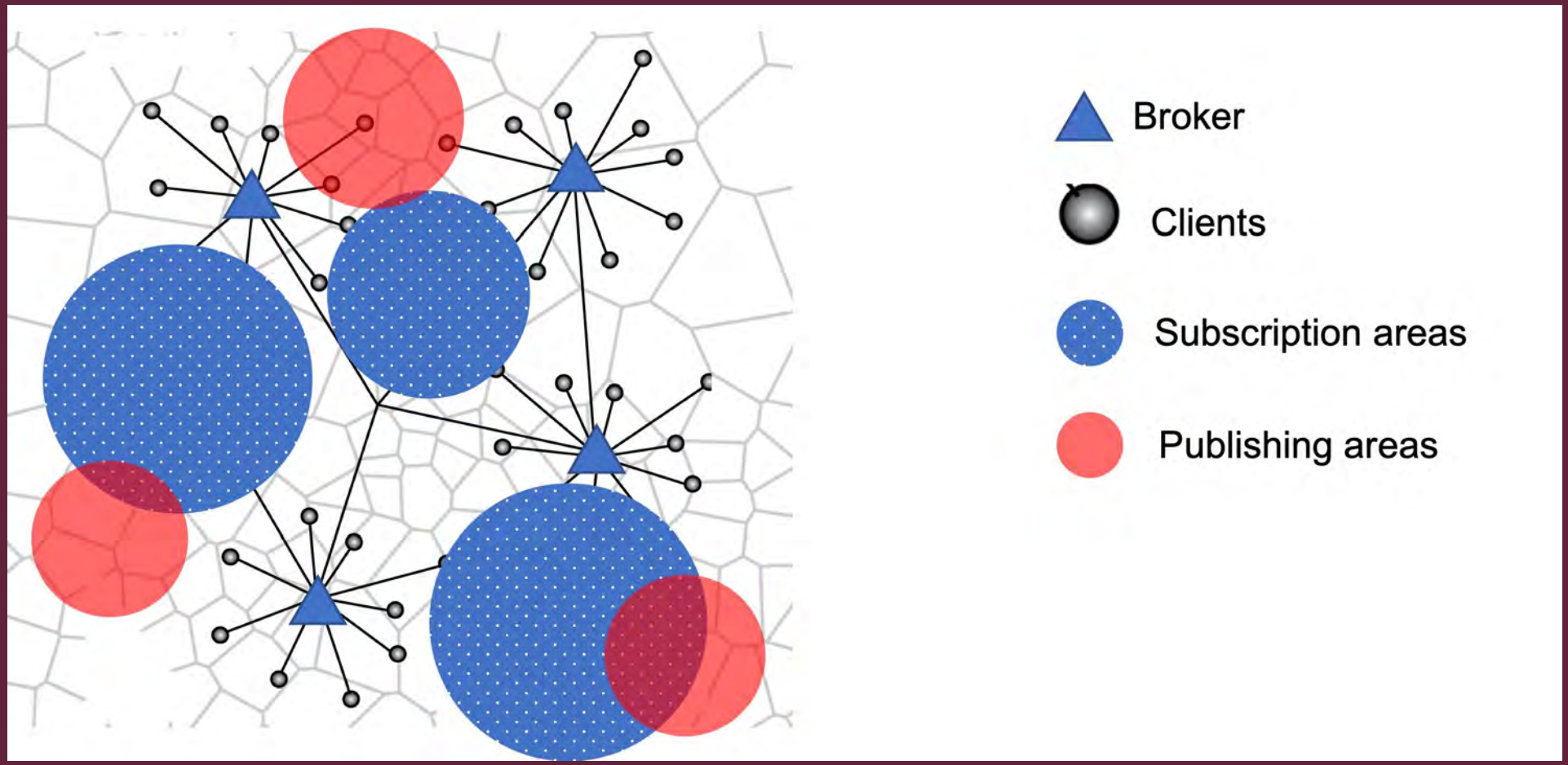
Decentralized Spatial Publish/Subscribe Configuration



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Where can Spatial Publish/Subscribe be useful?

- Sensor Networks
- Industrial Internet of Things (IIoT)
- Environment sensors that monitors buildings
- Home Automation
- Even online games…

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Open-source Library – VAST.js

- Open-source library that implements Spatial Publish/Subscribe available on GitHub (https://github.com/vastverse/VAST.js)
- Supports centralized configuration:
  - Single broker, multiple clients
- Supports decentralized configuration
  - Multiple brokers, multiple clients
  - Brokers exchange messages using peer-to-peer network

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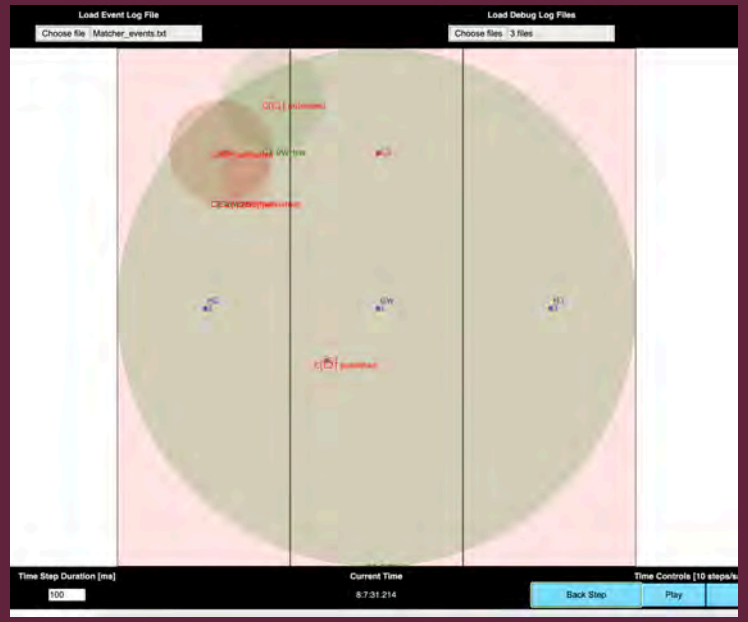
Open-source Library – VAST.js

- Includes simulator and visualizer allowing industry to test-drive Spatial Publish/Subscribe




```
// EXAMPLE INSTRUCTION SCRIPT FOR VAST.js Simulator
//_____________________________________________________________

//Start the Gateway matcher
newMatcher GW true localhost 8000 8001 20000 500 500 100
wait 100

//Start other matchers
newMatcher M2 false localhost 8000 8010 20010 167 500 100
newMatcher M3 false localhost 8000 8020 20020 833 500 100

// Start a few clients with localised subscriptions
newClient C1 localhost 20000 300 100 100
wait 200
subscribe C1 300 100 100 channel1

newClient C2 localhost 20000 200 200 100
wait 300
subscribe C2 200 200 100 channel1

// start a client with a huge subscription
newClient C3 localhost 20000 500 200 100
wait 400
subscribe C3 500 500 500 channel1
```

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Example of SPS using online game

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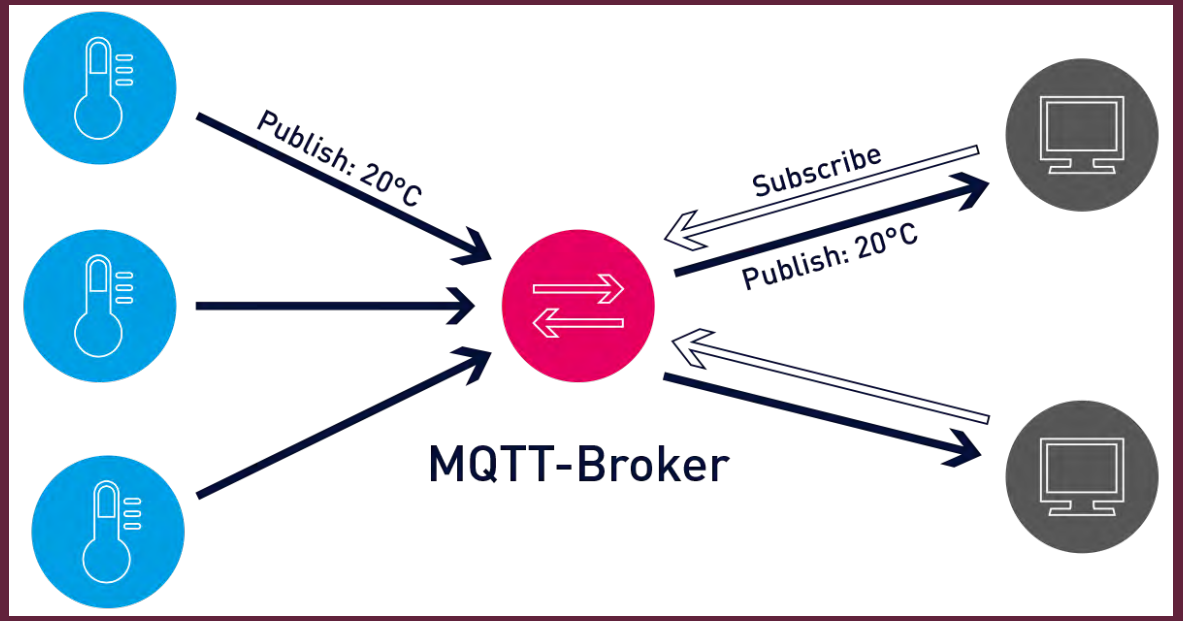
Extending MQTT to support Spatial MQTT

- Integrated Spatial Publish/Subscribe with MQTT
- Extended open-source MQTT broker
- Allows standard MQTT clients to publish spatial message



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Conclusions

- We presented Spatial Publish/Subscribe that allows IoT devices to efficiently communicate data with inherent spatial information
- VAST.js - An open-source implementation of Spatial Publish/Subscribe is available on GitHub (https://github.com/vastverse/VAST.js)
- VAST.js includes a simulator that allows industry to easily evaluate the use of Spatial Publish/Subscribe in their business
- Have developed an experimental extension for a MQTT broker that allows standard MQTT clients to use Spatial Publish/Subscribe (https://github.com/vastverse/aedes)

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Thank you
Enkosi
Dankie

Photo by Stefan Els

Engineering | EyobuNjineli | Ingenieurswese

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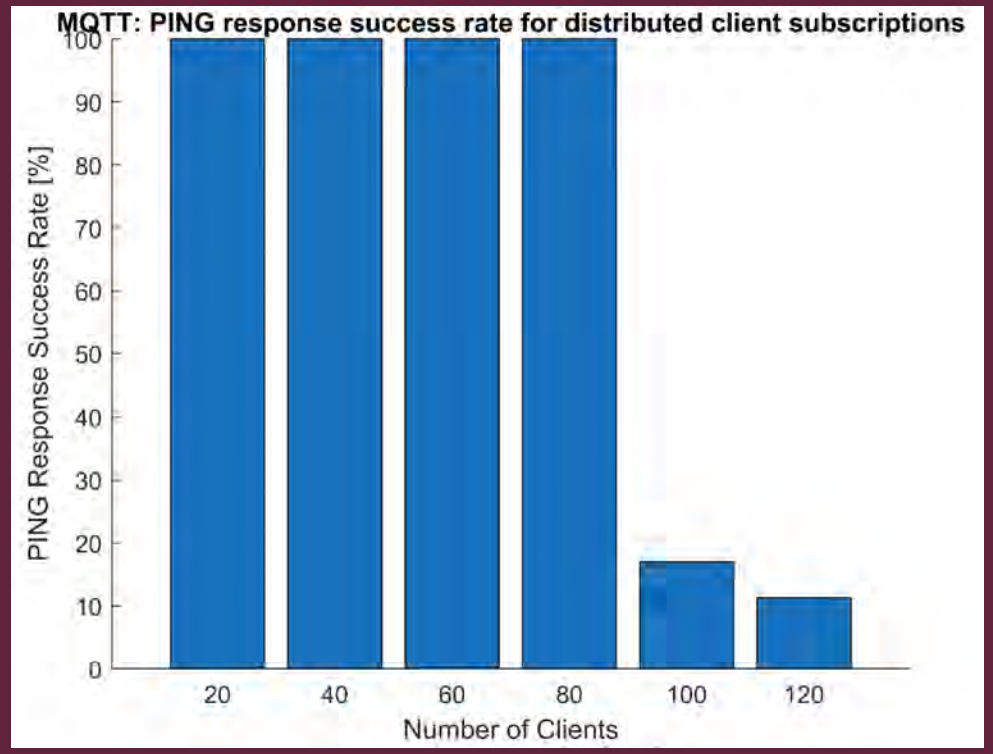
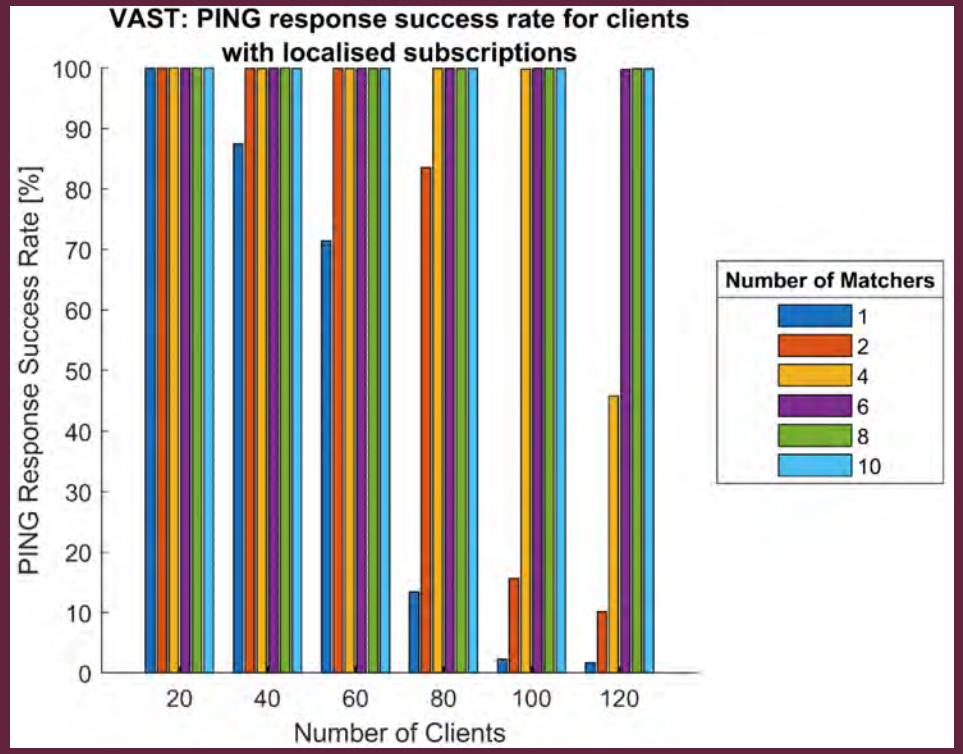
Performance – Response Rates

MQTT architecture with one broker



VAST architecture with multiple brokers



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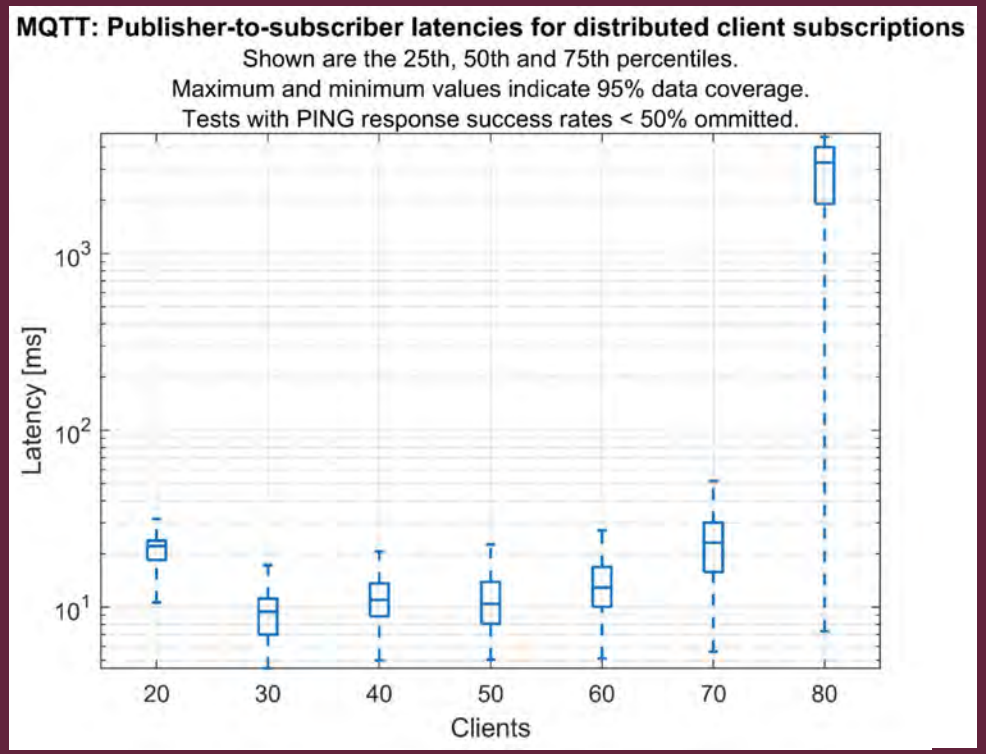
Performance – Latency

MQTT architecture with one broker



VAST architecture with multiple brokers