Spatial Internet of Things

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Overview of Presentation

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

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Internet of Things (IoT)

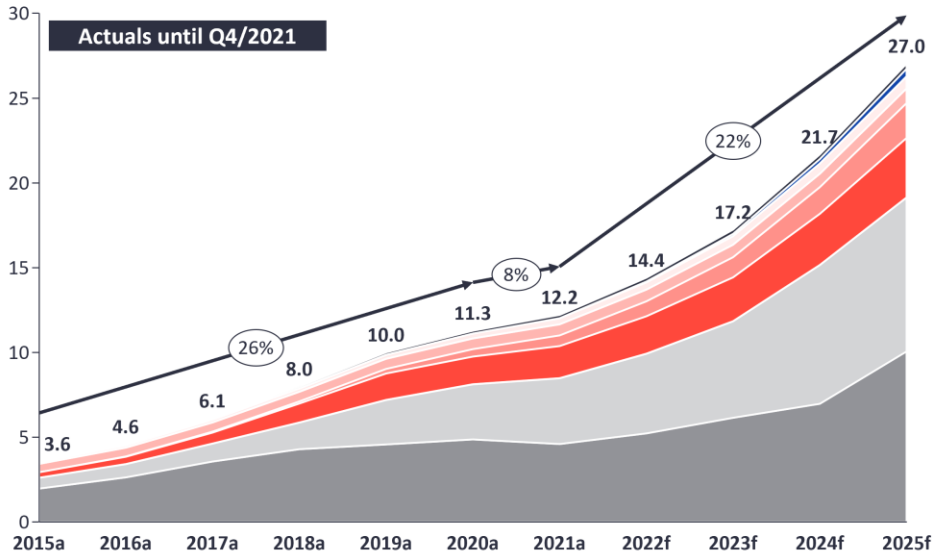
IOT ANALYTICS

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



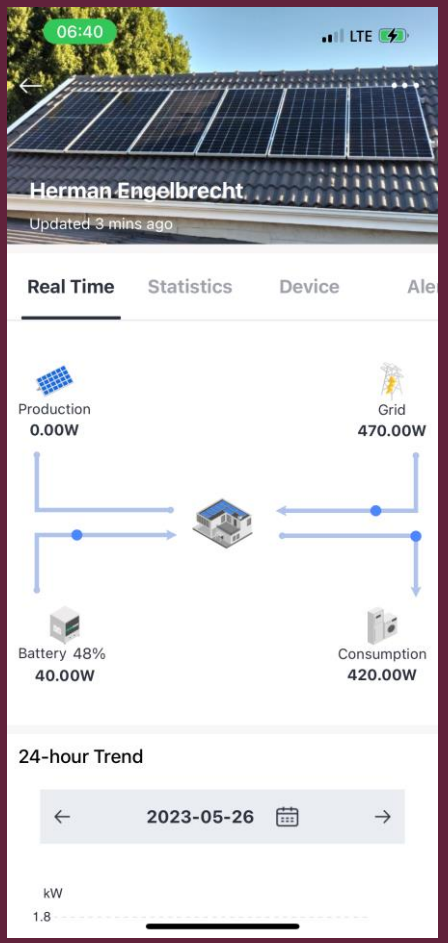
CONNECTIVITY TYPE	CAGR 20-21	CAGR 21-25
Wireless Neighborhood Area Networks (WNAN)	17%	11%
5G IoT	-	159%
Other	22%	20%
Wired IoT	4%	7%
LPWA	42%	34%
Legacy Cellular (2G/3G/4G)	16%	17%
Wireless Local Area Networks (WLAN)	19%	24%
Wireless Personal Area Networks (WPAN)	-6%	22%

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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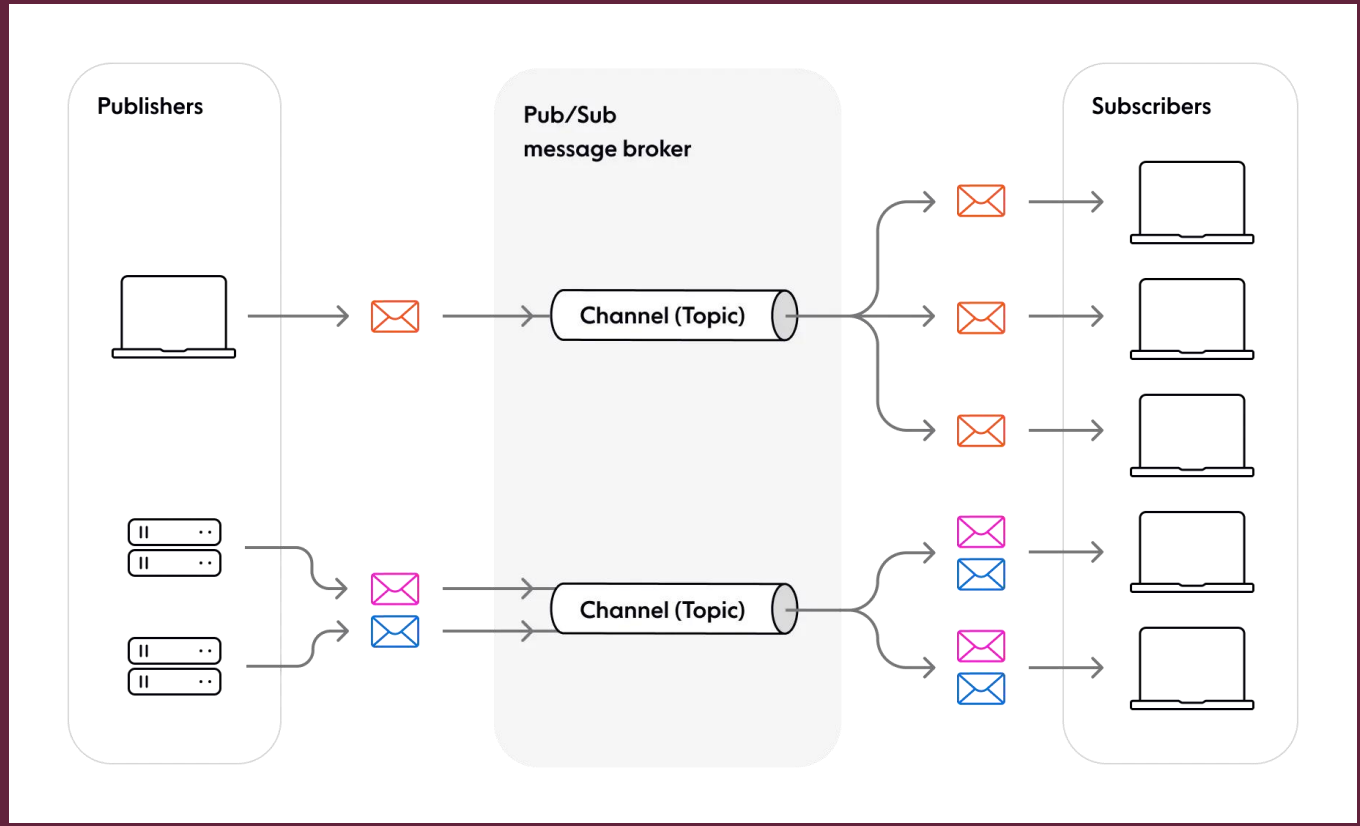
Publish/Subscribe Messaging Pattern

- 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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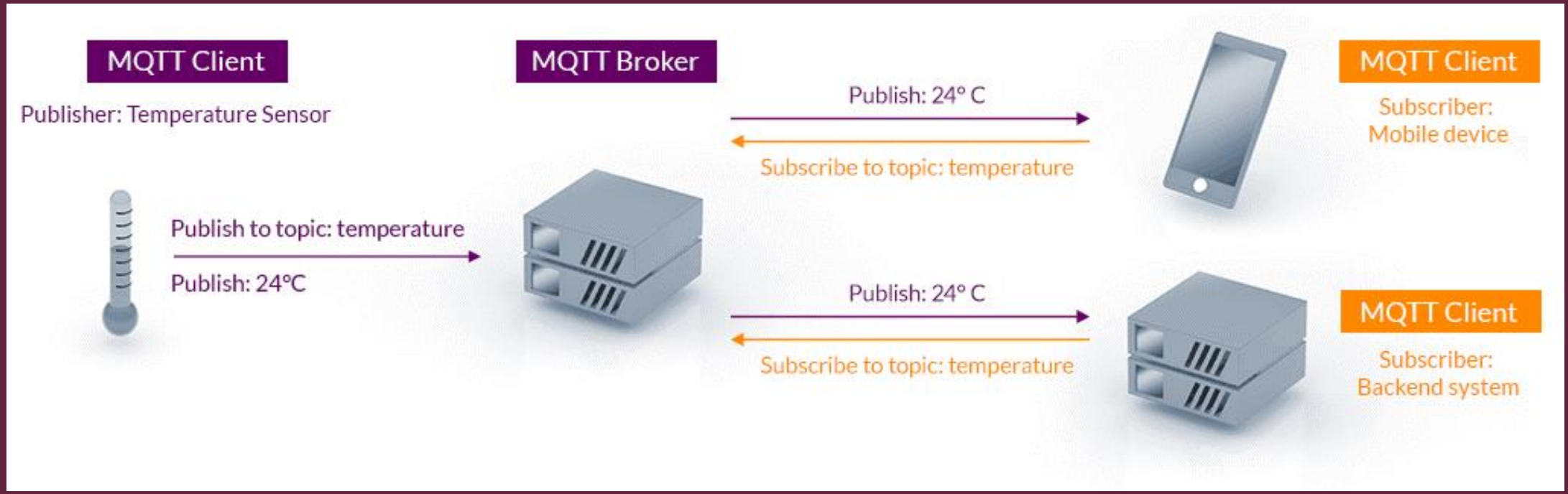
Topic-based Publish/Subscribe

- 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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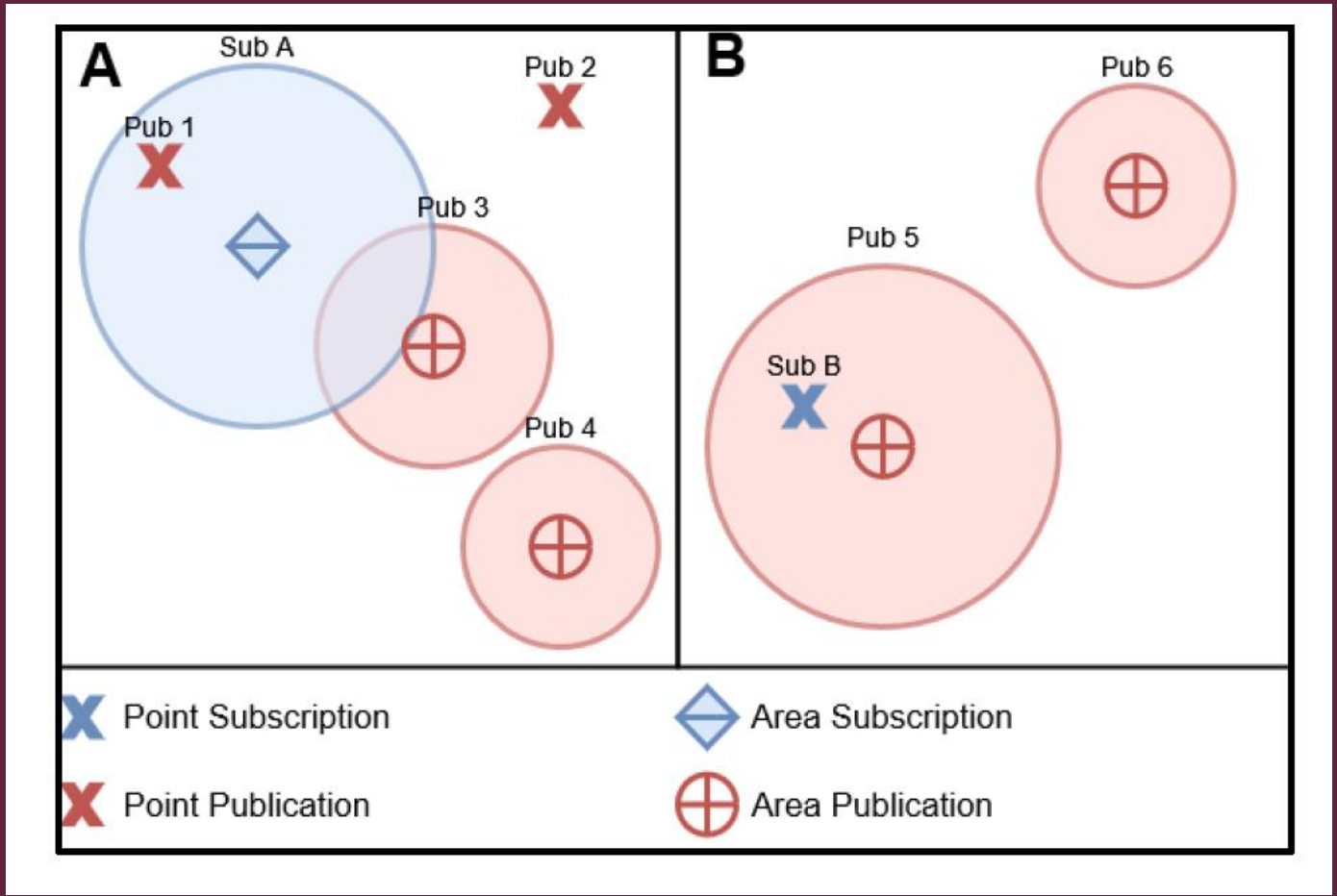
Spatial Publish/Subscribe



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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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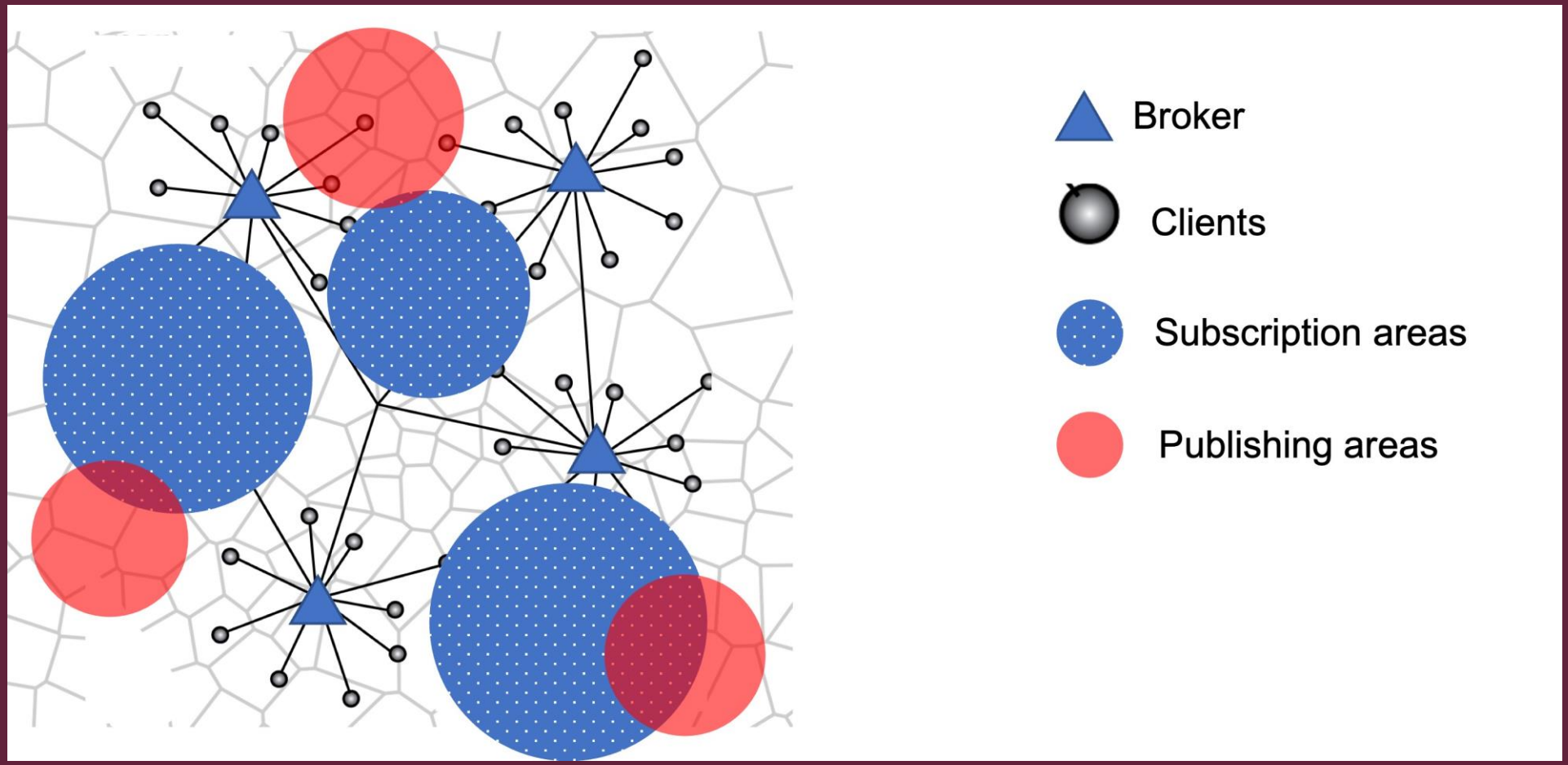
Decentralized Spatial Publish/Subscribe Configuration



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SPS Implementation – VAST.js (Open-source Library)

- 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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Where can Spatial Publish/Subscribe be useful?

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

Basic Network Architecture for Online Games

- The game state is stored (hosted) on a server connected to a network
- Users access the game world using a networked, client application

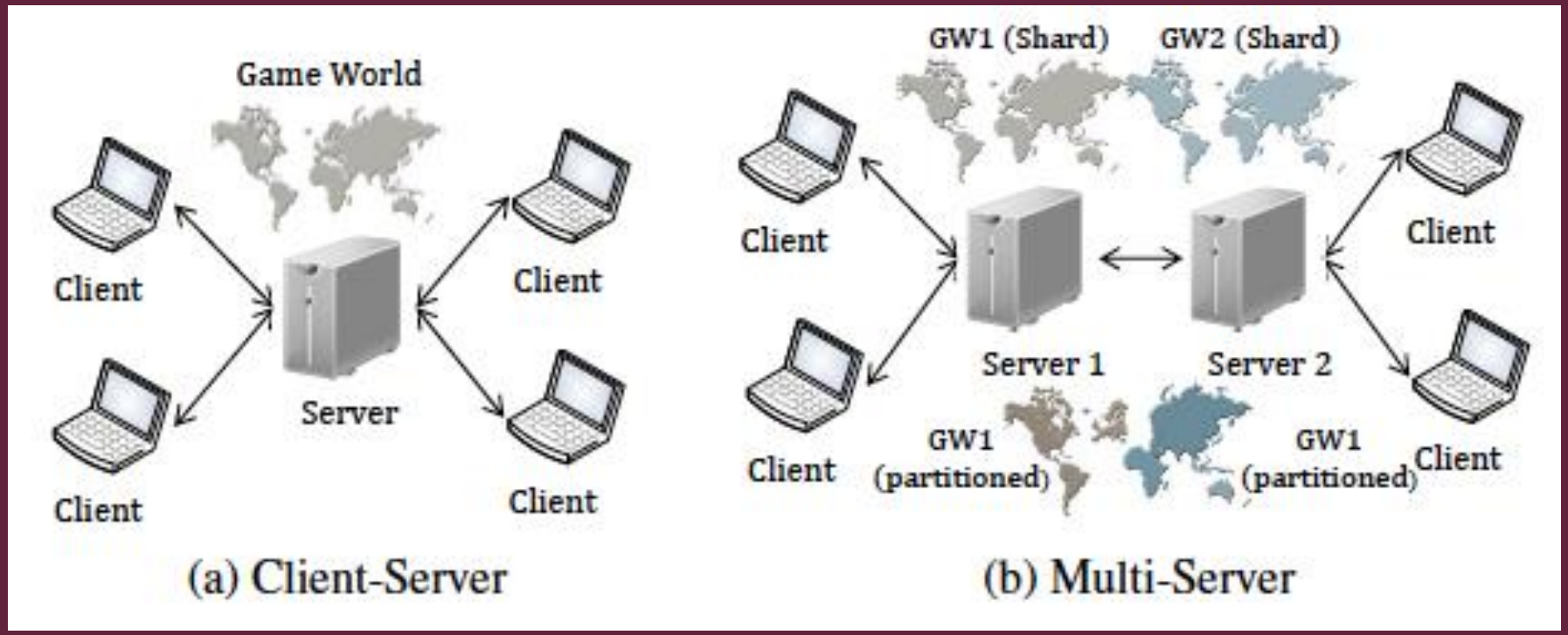

Figure from: Yahyavi, Amir, and Bettina Kemme. "Peer-to-Peer Architectures for Massively Multiplayer Online Games: A Survey." *ACM Computing Surveys* 1: 8022980

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Area of Interest Management

- Game architectures limit the communication between server and clients by using *Interest Management*
- Game state updates are typically location based
- Clients mostly interested in updates of state in area surrounding avatar
- Limit server communication by only sending state updates to clients if the location of the update falls within *Area of Interest* of client
- Publish/Subscribe does not filter on spatial information
- **Solution: Spatial Publish/Subscribe**

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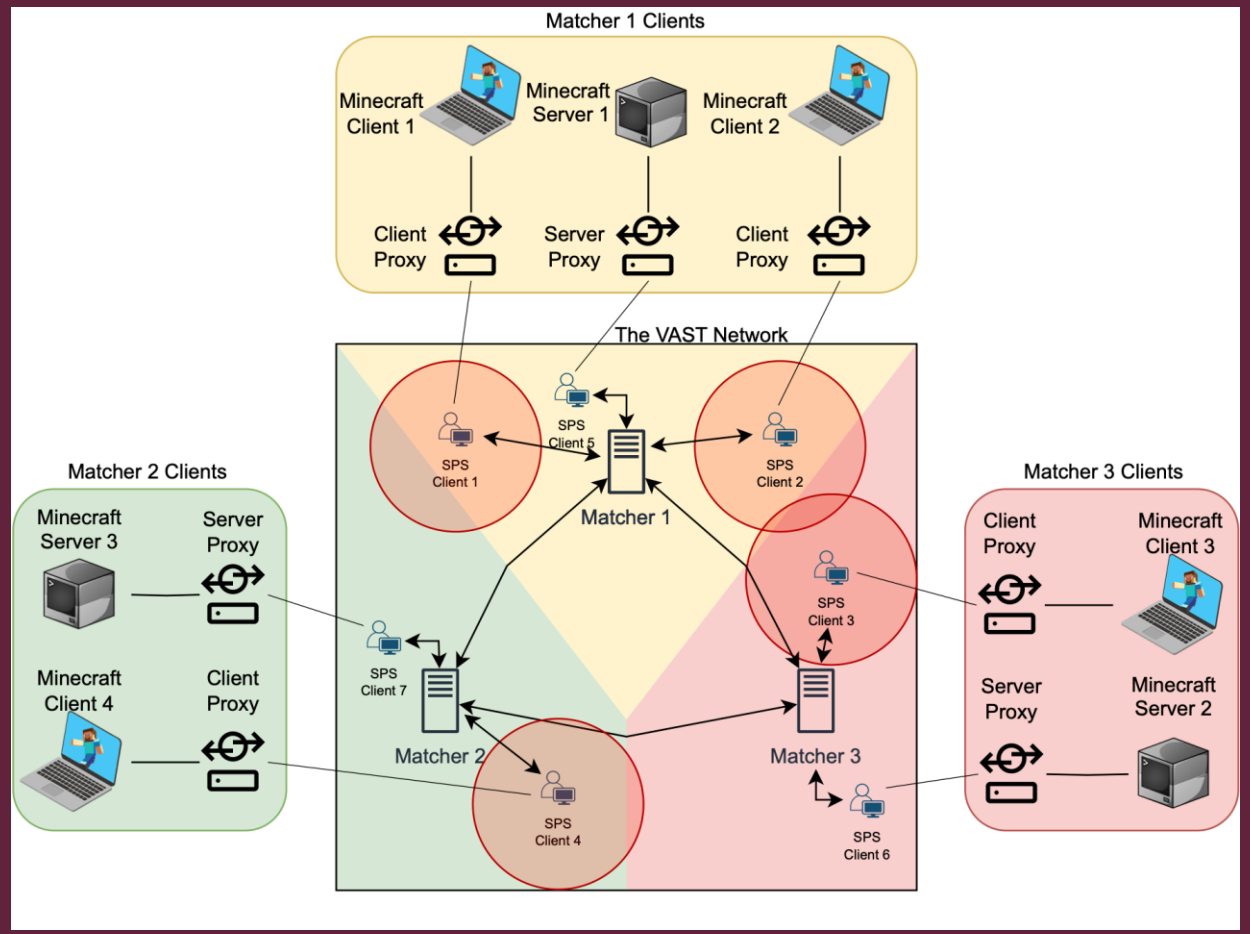
Koekepan+VAST: Spatial Publish/Subscribe Proof-of-Concept

- Clients send events to servers by publishing messages to the area around the avatar
- Minecraft Server is modified to only publish one message per state update
- Server/client communication is routed through Spatial Pub/Sub message brokers



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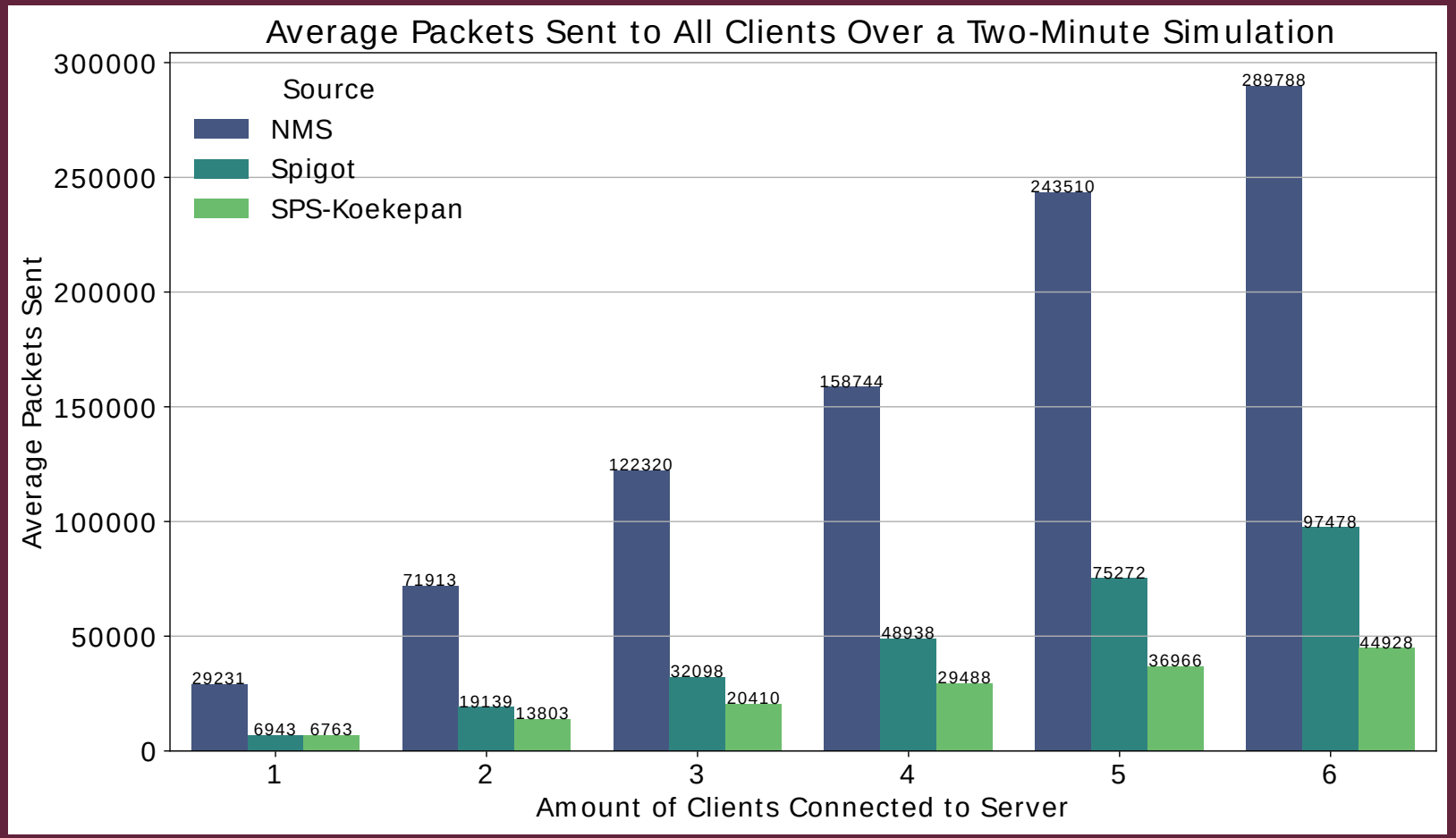
Koekepan+VAST: Scalability of Spatial Publish/Subscribe



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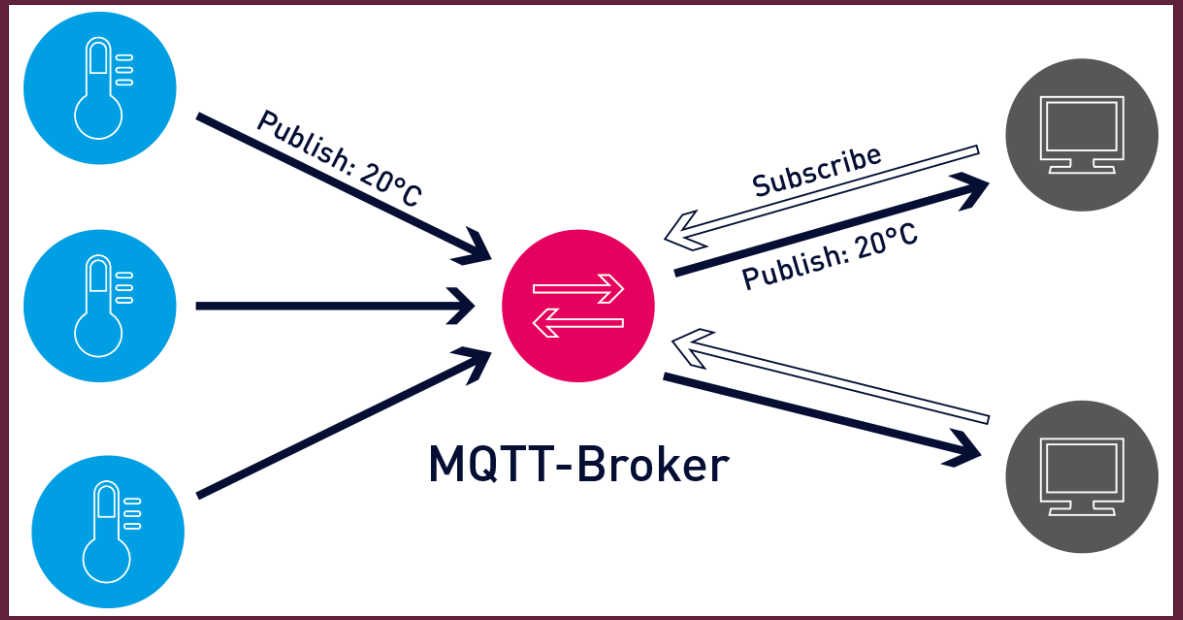
Extending MQTT to support Spatial MQTT

- 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