# 論文 / 著書情報
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# 論　文　要　旨（英文）　（800語程度）

（Summary）

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**In the context of event-driven application development, techniques of pub/sub messaging are promising candidates. Its paradigm provides not only real time dissemination by push-based delivery, but also high tolerance to the transition of relations between publishers and subscribers by their decoupling, e.g., each publisher does not need to be concerned about the location or status of subscribers that will receive its message. However, since a typical architecture has a centralized broker which gathers all published messages and forwards them to corresponding subscribers, it could be a bottleneck and a single point of failure. Especially when we consider handling IoT data, their characteristic of low value density makes the above issue much harder. Namely, a tremendous amount of data is concentrated on the broker with oppressing the network bandwidth, even though most of it will be discarded.**

**For overcoming the problem, this dissertation focuses on topic-based pub/sub systems which are one of the best known and widely used type of pub/sub systems, and introduces structured overlay networks into them. We assume an architecture, in which many brokers are placed on the edge of a wide area network and they cooperate with each other by composing a structured overlay network. This edge-based architecture makes latency lower as well as avoiding congestion on cloud resources, especially when producing and consuming data have geographical locality. We discuss about the architecture from the following three points of view.**

**At first, we propose a topic-based pub/sub method using Skip Graph, which is one of the algorithms of structured overlay networks supporting range queries. Although there are some existing studies of topic-based pub/sub messaging based on structured overlay networks, they have the problem of wasting network resources because of lacking adaptability to the characteristic of low value density in IoT data. In particular, the behavior that each publisher node continues to forward messages to a relay node even if there are no subscribers causes redundant messages between brokers. The proposed method regulates publishers and subscribers of the same topic to compose connected subgraphs so that publishers can detect the absence of subscribers and suspend sending messages. This mechanism reduces the redundant messages and thereby can minimize the load of wide area networks. We confirm the effectiveness of the proposed method quantitatively by simulation experiments.**

**Secondly, this dissertation focuses on the latency. The above proposed method involves the increase of the required time from publishers to subscribers, even though it brings about high scalability. This could impair the advantage of real time dissemination of pub/sub messaging. We discuss about the improvement of the latency from two aspects. The first one is routing algorithms of Skip Graph. There are several existing algorithms for handling range queries, but they are inefficient regarding the latency.**

**We propose a new algorithm named Split-Forward Broadcasting (SFB), and indicate that it can improve the latency by reducing the average number of hops. The second one is client assignment strategies. The latency is widely influenced by how to assign subscribers to each broker. There are two possible approaches: the intensive assignment by which subscribers having a same topic are accommodated on a same broker, and the extensive assignment by which the subscribers are accommodated on different brokers as far as possible. We formulate the difference of the latency between these two approaches, and discuss about the optimization of subscriber assignment.**

**Finally, this dissertation gives a discussion about developing the proposed method as a middleware, including the capability of a practical protocol. We focus on MQTT, which is one of the promising protocols for exchanging IoT data. Considering the edge-based architecture, heterogeneity could be a vital issue, i.e., an appropriate product of the MQTT broker could vary according to the different environment of each network edge. We propose Interworking Layer of Distributed MQTT brokers (ILDM), which enables arbitrary kinds of MQTT brokers to cooperate with each other. ILDM provides APIs which facilitate rapid development of variety of cooperation algorithms, including the proposed method. To clarify the feasibility of ILDM, we show two primitive cooperation algorithms which use the APIs, and evaluate on an actual environment. The evaluation is conducted by a benchmark method which we design to have the capability of measuring both a single broker and multiple brokers. Experimental results show that the throughput of multiple brokers running together by ILDM is improved significantly than that of a single broker.**