ABSTRACT

Explanatory note size – 110 pages, contains 9 illustrations, 34 tables, 4 applications, 25 references.

Topicality. The thesis examines the problem of reliable and efficient telemetry delivery in narrowband IoT networks NB-IoT and LoRaWAN, with the object being software for collecting, transforming and transporting IoT telemetry through an MQTT gateway. The main features of existing solutions based on MQTT/MQTT-SN/CoAP and ADR mechanisms are analysed, together with their advantages and limitations in constrained channels. The need is identified for developing a formally grounded adaptive MQTT gateway which tunes message rate, format and reliability to the actual channel state without any modifications to the broker.

The aim of the study. The main target is to increase the efficiency and reliability of IoT telemetry delivery over narrowband NB-IoT/LoRa channels by adapting message encoding, batching and QoS parameters in real time without changing the MQTT broker.

The object of research: software for collection, transformation and transportation of IoT telemetry in narrowband networks (NB-IoT/LoRa).

The subject of research: processes of design, modification and quality assurance of adaptive telemetry software, as well as methods for building and experimentally evaluating adaptive MQTT-gateway policies based on a functional policy algebra and functional reactive programming.

To achieve this goal, the **following tasks** were formulated:

- to analyse existing protocols and approaches to telemetry in NB-IoT/LoRa and the requirements to data-delivery quality;
- to define requirements, SLO/SLI and a model of network profiles for the new solution; to develop a functional policy algebra and an FRP-based channel-state model;

- to implement an adaptive MQTT gateway with MQTT v5 integration and without broker changes;
- to design an experimental methodology, emulate NB-IoT/LoRa channels and compare the adaptive scheme with a static one by efficiency and reliability criteria.

The scientific novelty of the results of the master's dissertation is that a compact functional policy algebra for adaptive telemetry in NB-IoT/LoRa and an SLO-driven FRP control model for an MQTT gateway are proposed. In contrast to existing approaches, they treat encoding, delta encoding, batching, rate limiting, reliability level and data freshness as a single formal processing pipeline with clear denotational semantics, rewriting laws and flow-stability invariants. The result was achieved by constructing an FRP-based channel-state model, introducing contractive policy updates and providing an operational mapping of the algebra onto MQTT v5 mechanisms (Receive Maximum, Maximum Packet Size, Topic Alias, Message Expiry) without broker modification.

The practical value of the obtained results is that a prototype adaptive MQTT gateway based on Scala/ZIO has been implemented, in which compression, delta encoding, batching and SLO-oriented flow control methods are combined inside a single application and remain fully compatible with standard MQTT v5 brokers without any changes on their side. A Prometheus/Grafana-based monitoring stack and a reproducible NB-IoT/LoRa testbed using tc netem have also been built, so the proposed gateway can be used as an intermediate software component in smart-city, agriculture, industrial telemetry, environmental monitoring and infrastructure-safety systems.

Relationship with working with scientific programs, plans, topics. Work was performed at the Department of Informatics and Software Engineering of the National Technical University of Ukraine «Kyiv Polytechnic Institute. Igor Sikorsky».

Approbation. The scientific provisions of the dissertation were tested at the The scientific results of the dissertation were presented and discussed at the VI International

Scientific and Practical Internet Conference “Information Technologies: Models, Algorithms, Systems (ITMAS–2025)” and the XVIII International Scientific and Practical Conference “Information Technologies and Automation – 2025”, where an applied implementation of the policy algebra and FRP-based control for MQTT v5 in NB-IoT/LoRaWAN was demonstrated.

Publications. The scientific provisions of the dissertation were published in:

1) Nikonorov A.O., Popereshnyak S.V. Functional policy algebras and reactive models for adaptive telemetry in resource-constrained networks // Science and Technology Today (Series “Engineering”). 2025, no. 10(51), pp. 1844–1861.
2) Nikonorov A.O. SLODRIFT: applied implementation of policy algebra and FRP-based control for MQTT v5 in NB-IoT/LoRaWAN // Information Technologies: Models, Algorithms, Systems (ITMAS–2025): Proc. of the VI Int. Sci.-Pract. Internet Conf. – Mykolaiv, Admiral Makarov NUS, 2025, pp. 385–387.
3) Nikonorov A.O. Functional policy algebra and FRP for stable adaptive telemetry in NB-IoT and LoRaWAN // XVIII Int. Sci.-Pract. Conf. “Information Technologies and Automation – 2025”. – Odesa: ONTU, 2025, pp. 854–856.

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