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Contact: Gyu Myoung LEE
Korea (Rep. of)

Tel: +82-10-6746-5754
Email: gyumyoung.lee@gmail.com

Abstract: This document contains the initial text of proposed draft new Recommendation ITU-T Y.DPM-Ambient-IoT "Functional requirements and architecture of data processing and management to support ambient power-enabled Internet of Things", based upon SG20-C418, resulting form the discussion and agreement of Q4/20 meeting (Geneva, 12-21 May 2026).

Recommendation ITU-T Y.DPM-Ambient-IoT

Functional requirements and architecture of data processing and management to support ambient power-enabled Internet of Things

Summary

[TBD]

Keywords

Data processing and management, Ambient power-enabled Internet of Things

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Recommendation ITU-T Y.DPM-Ambient-IoT

Functional requirements and architecture of data processing and management to support ambient power-enabled Internet of Things

1 Scope

This Recommendation specifies the functional requirements and architecture of data processing and management (DPM) to support the ambient power-enabled Internet of Things (IoT). In particular, this DPM architecture is designed to enable energy-aware data acquisition and processing, and to address data fragmentation and quality degradation inherent to ambient IoT devices.

The scope of the draft Recommendation includes:

- an overview of DPM to support ambient power-enabled Internet of Things;

- functional requirements of DPM to support ambient power-enabled Internet of Things;

- functional architecture of DPM to support ambient power-enabled Internet of Things.

2 References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.4602] Recommendation ITU-T Y.4602 (2023), *Data processing and management Framework for IoT and smart cities and communities*

[ITU-T Y.Ambient-IoT] Recommendation ITU-T Y.Ambient-IoT (2025), *Requirements and capabilities of ambient power-enabled Internet of Things*

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3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 Ambient-IoT device [b-3GPP TR 22.840]: An ambient power-enabled Internet of Things device is an IoT device powered by energy harvesting, being either battery-less or with limited energy storage capability (e.g., using a capacitor).

3.1.2 data processing and management (DPM) [b-ITU-T FG-DPM TS D0.1]: The combination of all activities either directly performed on or indirectly influencing data.

NOTE 1 – Directly performed activities include among others [collecting/acquiring/capturing], exchanging, storing, securing, manipulating, reusing, aggregating, curating, disposing, monetizing and deleting data.

NOTE 2 – Indirectly influencing activities include among others policy and standards making, skills and innovation enhancement.

3.1.3 Internet of things [b-ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

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3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 <Term 3>: <definition>.

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4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DPM	Data Processing and Management
IoT	Internet of Things
EHS	Energy Harvesting Status

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5 Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords “can optionally” and “may” indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor’s implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Overview of data processing and management to support ambient power-enabled Internet of Things

6.1 Concepts of ambient power-enabled IoT

An ambient power-enabled Internet of Things (IoT) device is an IoT device powered by energy harvesting, being either battery-less or equipped with limited energy storage capability [b-3GPP TR 22.840]. By relying on energy harvested from ambient sources, the ambient power-enabled IoT enables the development of lower-cost, smaller, and maintenance-free devices. This allows IoT deployments to become highly scalable and environmentally sustainable [Y.Ambient-IoT].

6.2 Data characteristics of ambient power-enabled IoT

Unlike traditional IoT devices equipped with stable power sources (e.g., continuous grid power or long-life batteries), ambient power-enabled IoT devices rely entirely on harvesting energy from their surroundings. This fundamental shift in the energy model introduces unique characteristics to the data processing and management (DPM) within the ambient power-enabled IoT system.

The primary data characteristics of the ambient power-enabled IoT include:

- **unpredictable data intermittency:** data generation and transmission are strictly constrained by the real-time energy harvesting status (EHS). Data streams are often discontinuous, leading to unpredictable data arrival rates, fragmented data packets, and potential data loss during frequent power-off and recharge cycles;
- **strict energy-data dependency:** in the ambient power-enabled IoT, data cannot be managed independently of energy. The timing, volume, and quality of data acquisition are directly dictated by the real-time availability of harvested energy, requiring data management operations to be highly "energy-aware";
- **severe energy limitations and asymmetric processing:** due to extreme computational constraints, ambient power-enabled IoT devices lack the capacity for continuous operation, local data buffering, or complex on-device processing. They typically transmit raw, minimal payload data. Consequently, the burden of data aggregation, cleansing, and formatting is entirely shifted to the network edge, necessitating edge-assisted data reconstruction;
- **massive scale with high spatial redundancy:** ambient power-enabled IoT devices are expected to be deployed in massive quantities at a very low cost. This generates a massive volume of spatially correlated and potentially redundant data, requiring highly efficient deduplication and aggregation mechanisms to prevent network congestion.

To quantify the strict energy-data dependency, the EHS of ambient power-enabled IoT devices can be classified into distinct levels. These EHS levels directly dictate the device's data generation and processing capabilities, as illustrated in Table 1.

Table 1 - Energy Harvesting Status (EHS) classification

EHS Level	Description	Typical Capability
EHS-0	No energy	Device cannot perform any communication or sensing; only energy harvesting possible.
EHS-1	Backscatter-only	Device can perform backscatter communication; no active transmission; no local data processing; may support event-triggered reporting.
EHS-2	Low-power active	Device can perform low-power active transmission ; minimal local processing; reduced sampling rate; may also support backscatter.
EHS-3	Normal active	Device can perform normal active transmission; local processing; normal sampling rate.

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6.3 Mapping of DPM capabilities to the energy-aware operational cycle of ambient power-enabled IoT system

Table 2 illustrates how the conventional DPM capabilities defined in Recommendation ITU-T Y.4602 are mapped to the energy-aware operational cycle of ambient power-enabled IoT system. Specifically, it demonstrates how standard DPM operations are adapted to address the challenges of the ambient power-enabled IoT by accommodating the dynamic nature of ambient energy harvesting and mitigating the inherent degradation of data quality.

Table 2 - Mapping of DPM capabilities to the energy-aware operational cycle of ambient power-enabled IoT system

DPM Capabilities [ITU-T Y.4602]	**a) Acquiring ambient energy harvesting status**	**b) Formulating harvesting-adaptive policies**	**c) Executing ambient energy-aware operations**	**d) Monitoring and collecting feedback**	**e) Optimizing policies via closed-loop**
Data creation and acquisition	Ambient energy and data quality context tagging	-	Harvesting-adaptive sampling & fragmented data acquisition	-	-
Data processing	Harvesting-state mapping	Ambient energy and quality-aware processing policies	-	-	Predictive harvesting and data yield optimization
Data categorization	-	Intermittency tolerance & data quality requirement profiling	-	-	-
Data aggregation	-	Harvesting-weighted and quality-aware merging rules	Edge-assisted data fusion (fragmentation mitigation)	-	Ambient energy vs. data quality trade-off learning
Data masking, cleaning and organization	-	-	Edge-assisted data reconstruction (handling harvesting-induced gaps and low-quality data)	-	-
Data transmission and storage	-	-	Harvesting-gated transmission for fragmented data & deferred storage	-	-
Data monitoring and validation	-	-	Harvesting-conditional task offloading	Dual validation (data quality & ambient energy cost)	-

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8 Functional requirements of data processing and management to support ambient power-enabled Internet of Things

<TBD>

7 Functional architecture of data processing and management to support ambient power-enabled Internet of Things

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Appendix I

Use cases of DPM to support ambient power-enabled Internet of Things

(This appendix does not form an integral part of this Recommendation.)

I ambient power-enabled IoT for Passive Asset Tracking in Smart Warehousing

I.1 Scenario Description

This use case applies to a large-scale smart warehousing environment, where massive quantities of goods, pallets, and turnover boxes require real-time, full-lifecycle asset tracking. Traditional active RFID tags and battery-powered IoT devices require regular battery replacement and maintenance, leading to high operational costs, labour input, and environmental hazards from depleted batteries. In this scenario, ambient power-enabled IoT RF-BC tags are affixed to each asset, harvesting ambient RF energy from existing warehouse WiFi, UHF reader, and cellular network signals to achieve battery-free, maintenance-free operation.

I.2 Core Pain Points Addressed

Dynamic Energy Fluctuation: RF signal strength varies significantly across different locations in the warehouse: tags on open shelves have sufficient energy, while tags deep in high-bay racks or stacked goods have extremely limited harvestable energy. Fixed data acquisition and reporting rules lead to frequent device downtime, data loss, and asset visibility gaps.

Massive Device data management: A single warehouse may deploy a large volume of ambient power-enabled IoT tags, generating massive small-size data packets. Traditional DPM solutions cause severe network congestion, high data processing overhead, and low data utilisation efficiency.

Lightweight Security Requirements: Warehouse asset data involves commercial confidentiality, but RF-BC tags have no capability to support traditional complex encryption algorithms, leading to risks of unauthorised access and data tampering.

I.3 Implementation Scenarios

Energy harvesting status Classification and Adaptive Data Acquisition: Each tag dynamically assesses and categorises its energy harvesting state according to real-time collected RF energy. Tags with lower energy availability only send basic asset identification at extended intervals; those with sufficient energy harvesting capability report comprehensive information including asset ID, location, and environmental data (temperature, humidity) at more frequent intervals, alongside immediate transmissions when abnormal events are detected.

Edge-Cloud Collaborative Data Processing: Warehouse gateways receive tag data, aggregate large volumes of small data packets, remove redundant information, and perform lightweight data validation. This approach substantially reduces data transmission overhead to the cloud platform, greatly optimising overall transmission efficiency.

Cross-Layer energy data Scheduling: The warehouse gateway dynamically adjusts the RF signal transmission window and tag polling strategy, prioritising polling of tags in low energy harvesting status areas to ensure basic asset visibility, while optimising the polling frequency of tags in high energy harvesting status areas to avoid network congestion.

I.4 Expected Benefits

Zero Maintenance Cost: Battery-free operation removes the expenses and labor costs associated with regular battery replacement for massive scale tag deployment, effectively cutting overall operational expenditure versus conventional active asset tracking solutions.

Asset Visibility: The energy-aware adaptive mechanism ensures continuous operation of all tags, eliminating asset visibility gaps caused by device downtime and significantly boosting inventory accuracy to an industry-leading level.

Efficient data management: Edge data aggregation and adaptive transmission drastically reduce network load to a fraction of the original load, while upholding the integrity and reliability of core asset data.

Sustainability: Battery-free design eliminates hazardous waste from depleted batteries, supporting the sustainable development goals of the warehouse and smart sustainable cities and communities.

Bibliography

[b-ITU-T FG-DPM TS D0.1] Technical Specification D0.1 (2019), *Data Processing and Management for IoT and Smart Cities and Communities: Vocabulary*.

[b-3GPP TR 22.840] 3GPP TR 22.840 (2023-09), Study on Ambient power-enabled Internet of Things.

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