Ambient IoT: Redefining Wireless Communication for Industry 4.0

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The concept of Industry 4.0 represents the ongoing trend of automation and digitalization within manufacturing and other industries. The technologies involved in fulfilling the requirements for it rely on real-time data collection, analysis, and decision-making, to achieve more optimized production processes, predictive maintenance, and customized manufacturing.

Internet of Things (IoT) technologies can fulfil these requirements, making it a key enabler in materializing Industry 4.0 over future wireless technologies. Hence, it is imperative that the IoT devices be connected to the cellular network.

## The potential of Ambient IoT

For the massive deployment of IoT devices and the growth of the IoT market, future wireless technologies must be sustainable and energy efficient. However, the existing cellular IoT technology, relying on battery-powered devices, poses maintenance, environmental impact, and safety challenges, especially in critical industries.

Addressing these issues requires IoT technologies supporting battery-less or low-energy devices. Devices operating on energy harvesting technology have the potential to address the problems of scaling up the battery-powered IoT network. These devices are expected to be battery-free, harvesting the energy from ambient sources such as electromagnetic, thermal, and solar. They will operate with limited energy storage capacity and will not require battery charging or replacement. 3GPP is currently studying this new class of IoT devices, termed as 'Ambient IoT' (AIoT) devices, which will be integrated with cellular technology to meet the requirements mentioned above.

In an AIoT network, as shown in Figure 1, a device communication is powered by the energy harvested from an ambient energy source. The device interacts with the network via a reader node, which could be a base station or a user equipment (UE), which is capable of AIoT operation. Considering a device complexity and power consumption, ambient IoT Technology encompasses energy-harvesting devices, which are capable of active signal generation or backscattering for their data transmission.

Devices capable of active transmission are expected to use the harvested energy for their signal generation and transmission. Backscattering devices will rely on an externally-provided carrier wave for their signal transmission. These devices will modulate data on an externally provided carrier wave and reflect it toward the reader node. From the reader node’s perspective, backscattering ambient IoT devices can be in both monostatic and bistatic modes of operation. For monostatic operation, the reader node serving a particular AIoT device will provide the carrier wave to the AIoT device for signal transmission. For bistatic operation, the carrier wave source for AIoT signal transmission is a node which is different than a reader node that serves a particular AIoT device.



Figure 1: Ambient IoT network

All these device types are envisioned for different use cases based on the quality-of-service requirements.

Ambient IoT is envisioned to operate without having a dedicated power source to cater to very low-end IoT applications, such as inventory management and command, where the requirements include ultra-low complexity devices with ultra-low power consumption and a small form factor. Existing cellular IoT technologies cannot meet an AIoT device's low cost/complexity and power consumption requirements. This requires standardizing new technologies in Release 19 or later.

### AIoT in 3GPP today

So far, to bridge this gap in available technologies, in the Release 19 specifications, 3GPP initiated a study on AIoT in Service and Systems Aspect working group 1 (SA1) to capture use case, traffic scenarios, service requirements, and KPIs. The results of this study were captured in TR 22.840. Other SA working groups are currently looking into service architecture, security aspects, and the charging aspects of Ambient IoT devices.

Apart from the SA1 study, a parallel study at the RAN Plenary level was carried out to check the feasibility of meeting the design targets for relevant use cases of this new 3GPP IoT technology for deployment in a 3GPP system. The results of this study were captured in TR 38.848. Based on the results of the RAN Plenary study, in Release 19, a RAN working group-level study on Ambient IoT is on-going.

TSG RAN working groups are currently studying the air interface design for AIoT and the coexistence aspect of AIoT with NR technologies. Ambient IoT technology is anticipated to enhance current 3GPP IoT technologies by expanding into new markets, to create opportunities to serve low-end use cases with a significantly high local device density. Moreover, AIoT also aims to offer devices with substantially reduced complexity and power consumption. This emerging cellular IoT technology has the potential to address connectivity challenges, facilitating real-time data collection, analysis, and decision-making processes.

With these enabling technologies, Industry 4.0 has the potential to revolutionize operational excellence and streamline supply chain processes. For big markets such as India, the need for optimized production, logistics, and supply chains is ever-increasing.

The Digital India Initiative by the Government of India encourages the rapid deployment of 5G networks across the country, and through the Bharat 6G vision there is considerable support for the design, development and deployment of 6G network technologies that will enable Industry 4.0. Further, the ongoing study of AIoT on various use cases has the potential to complement the requirements of Industry 4.0. Ambient IoT cost-effectiveness and massive scalability make it a suitable candidate for widespread adoption across the Indian landscape.

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