Internet-of-Things

Technology Overview

2.1.1 The Internet-of-Things (IoT) promises to change the way society operates in the years ahead. IoT is a network of uniquely identifiable "things" that communicate without human interactions. IoT connects things any time, any place, with anyone and with any service. Its emergence will revolutionise the way we gather, analyse, and distribute data, thereby transforming life, business, and the global economy by 2025[7].

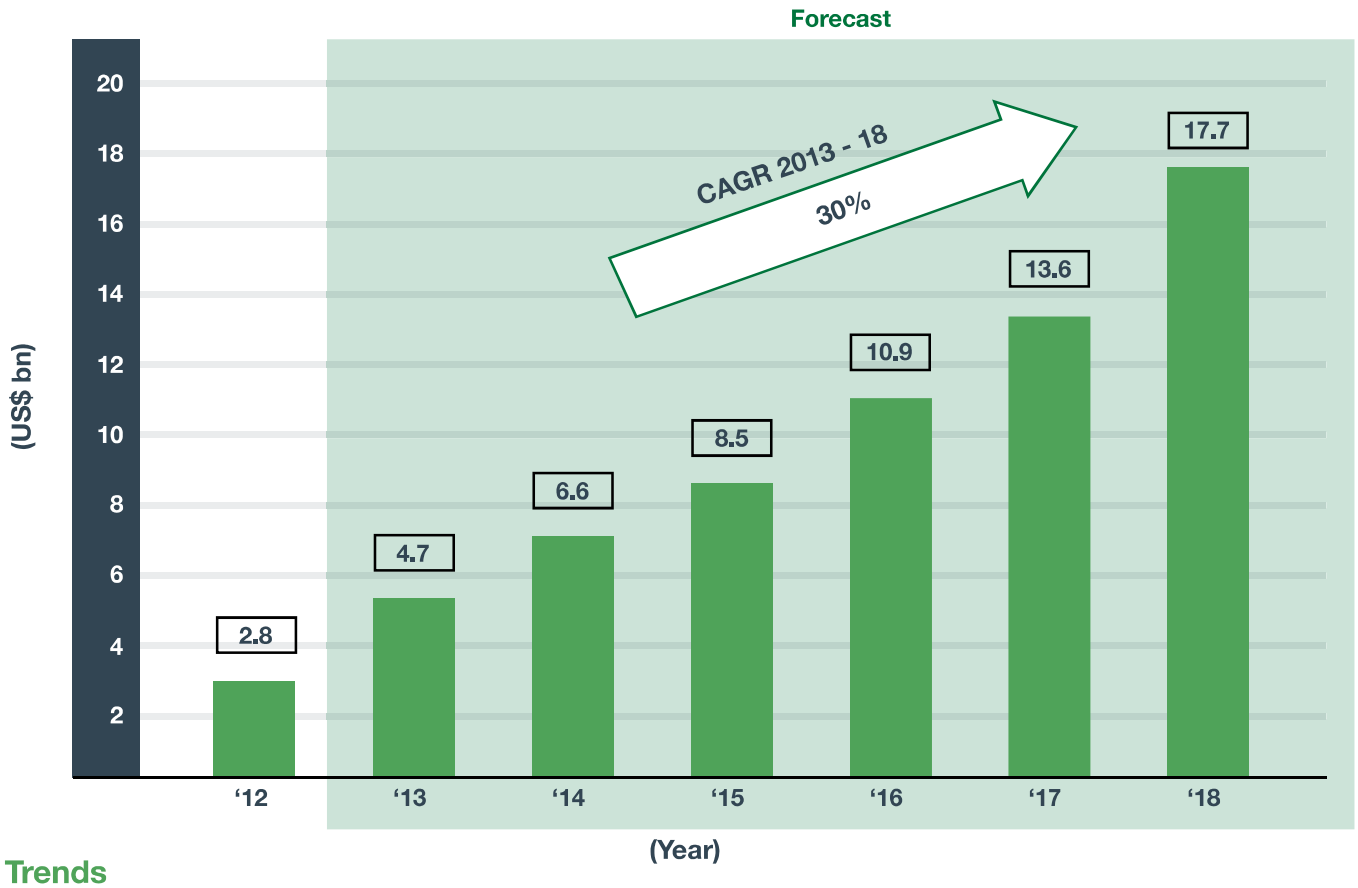
2.1.2 IoT evolved from "Machine-to-Machine" (M2M) technologies allow devices to share information and perform actions without human intervention via networks. Machines use network resources to communicate with remote applications for monitoring and control. In 2013, M2M connections accounted for 2.8 per cent of global mobile connections indicating that the sector is still young in its development. This is expected to grow in the next decade, seeing 44-fold growth from 2013 to 2018, and will account for six per cent of total mobile data traffic by 2018.

Market Size

2.2.1 The global IoT market is projected to reach US$800 billion by 2018, with a five-year CAGR (2013 – 2018) at 30 per cent. Singapore's addressable market globally for IoT is estimated to be US$18 billion by 2018 with a 30 per cent CAGR, as shown in the figure below. Apps make up about 80 per cent of IoT market revenues which offers a huge business opportunity for App developers, including start-ups.

2.2.2 In investments[8], global public funding agencies mainly focus on ultra-low power and sensing technology, both investing US$167 million and US$135 million, respectively. Venture Capitalists (VCs) invested US$2.8 billion on IoT applications and US$1.3 billion on sensing technology. Mergers and Acquisitions in the private sector concentrated on apps, and ultra-low power electronics, with investments of US$1.7 billion and US$0.6 billion, respectively.

Singapore's Internet of Things Addressable Global Market, 2013 - 18 (US$ bn)
CAGR = Compound Annual Growth Rate



Trends

2.3.1 Wearable Computing Devices (Wearables): Wearables like Smart Watches, Smart Bands, and Smart Jewellery are key drivers for efficient, smaller and smarter devices. The worldwide wearables market tripled in 2013, shipping 6.2 million units compared to 1.5 million units shipped in 2012. With more vendors entering the market, more capabilities being introduced, and more applications being launched, the wearables market is forecasted to grow five-fold in the next five years. This will result in an 18-fold increase in mobile data traffic.

2.3.2 M2M Explosion: M2M has a wide range of applications in, for example, industrial automation, logistics, Smart Grid, and Smart Cities, for monitoring and control purposes. M2M will see explosive growth in the next five years. Some M2M devices such as tele-health and autonomous vehicle devices, demand stringent guarantees on network data rate and latency. Supporting the explosion of M2M devices will require new communication protocols for low power and low cost M2M interoperability, new networking addressing schemes and sensor network automation to easily manage a large number of sensors.

2.3.3 Larger, More Integrated IoT Systems: A good example of this is Smart Transportation, where autonomous vehicles communicate with each other and the infrastructure it runs on, thereby creating a single real-time system. This sort of IoT ecosystem comprises many components, and it will be a challenge to standardise and scale them globally[9]. Virtualisation is possibly one solution. It adapts software in a single piece of hardware for multiple purposes, allowing the hardware to become "resources on-demand".

2.3.4 Industrial Internet: This integration of physical machinery with networked sensors and software draws upon Machine Learning, analytics, IoT, M2M and cyber-physical system to ingest data from machines, analyse it, and apply it to adjust operations. It paves the way for Smart Factories, and will drastically improve engineering, production, logistics and life cycle management processes in industries.

2.3.5 Demand of Smart City: Smart Cities make use of smart devices and other info-communications technologies to deal with challenges such as rising urban density, aging populations, pollution, water scarcity, public safety, as well as rising demands on education, healthcare, and social services.

Technology Roadmap

2.4.1 This table reflects the industry's view of the likely evolution and mainstream adoption of IoT technologies.

Demand Drivers	1-2 Years	3-5 Years	>5 Years
Smaller Smarter Devices	**System on Chip (SoC)**	**More than 10 Functions on a Single Chip**	**Nano Scale Integration**
	• Multi protocol chip • Integrated sensor solution • Cost effective high vol mfg • Photonic sensing[T]	• More than 10 functions on a single chip • Cost effective 3D packaging for heterogeneous integration • Carbon nanotube[T] • Single chip radios[T] • On-chip network[T] • On-chip antenna[T]	• Nano-scale sensors • Polymer based sensors • Graphene[T]
Energy Efficient Devices	**Ultra-Low Power Devices and Short Range Wireless Power Transfer**	**Multiple Power Sources Devices and Mid-Range Wireless Power Transfer**	**Nano-Power Devices and Long Range Wireless Power Transfer**
	• Energy harvesting devices • Adaptive energy harvesting • Super-capacitor • Ultra-low power chip sets • Short range wireless power transfer (a few centimetres) • Printed batteries[T]	• Energy harvesting base stations/relays in cellular network • Multiple power sources • Self-powering sensors • Mid-range wireless power transfer (tens or hundreds of metres) • Paper-based batteries[T]	• Energy efficient protocol and circuit for cellular comms • Nano-power processing unit • Long-range wireless power transfer (Kilometres) • Biodegradable batteries[T]
Intelligent Sensor Network	**Self-Discovery at Node Level**	**Self-Discovery at Service Level**	**Intelligent Self-Learning**
	• Node Self-discovery • Zero-configuration networking • Distributed decision making	• Service Self-discovery • Sensor fusion • Self-configurable	• Self-learning • Distributed intelligence • Intelligence at the edge
Interpera-bility	**Interoperability at Messaging Level**	**Interoperability at Information Level**	**Interoperability at Knowledge Level**
	• Domain Specific Sensor Ontology (e.g., transport and healthcare) • Multi-radio Gateway • Vehicle to Infrastructure • Extensible Messaging and Presence Protocol (XMPP)[T] • Data Distribution Service (DDS)[T] • Message Queue Telemetry Transport (MQTT)[T] • Constrained Application Protocol (CoAP)[T]	• Common sensor ontology • Vehicle-to-vehicle • P2P Messaging[T]	• Semantic interoperability • Vehicle-to-grid • Vehicular ad-hoc network • Vehicle-to-everything • Position-based routing[T]

[T] is classified as Technology, otherwise as Capability.
Industry has differing views on the timeframe for mainstream adoption for some technologies.

Adaptable and Easy-to-Use Middleware	**Standalone Middleware**	**Web Solutions to Map Physical Things into Existing Web**	**Intelligent Web**
	• Distributed Complex Event Processing (CEP) • Common service platform	• Virtualisation middleware (sensors and network) • Web of Things[T]	• Semantic Web[T]
IoT Security	**Device and Transmission Security**	**End-to-End M2M Security**	**Integrated Security Covering Service and Communications**
	• Device authorisation and access control • ZigBee, Z-Wave, Wirelss USB and Bluetooth security[T]	• M2M Security • Trusted third party devices and interfaces • Device integrity and privacy	• Scalable device management and behaviour verification

[T] is classified as Technology, otherwise as Capability.
Industry has differing views on the timeframe for mainstream adoption for some technologies.

R&D Opportunities

2.5.1 We need to align our national R&D efforts with the industry and sector development directions in the Infocomm Media 2025 report. This table highlights some examples of technology capabilities in the area of IoT that we need to build to support the appropriate sector transformations described in Chapter One.

Targeted Capabilities	Sector	Next Practices (3-5 years)	Transformational Practices (>5 years)
Sensors and Wearables	Health & Wellness	**Preventive Health**	**Digitised, Personalised Healthcare**
		• Low power, low cost, low area/footprint and real time embedded system design and algorithm for wearable • Intelligent wearables that are able to self-configure and self-record of bio-metric data • Seamless interaction with ambient sensors and appliances in home and public areas	• Long range wireless power transfer for wearables • Ability for wider sensing through nano-scale sensors which can be embedded in a variety of personal belongings, e.g., wearables, furniture, utensils, etc. • Distributed and Complex Event Processing (CEP)
	Transport	**Context-Aware & Data-Driven Intelligence**	**Smart Integrated Transportation System**
		Self-sustainable, low power smart sensors capable of interacting with cars and infrastructure, as well as collecting/sensing data from multiple sources	Robust and scalable vehicle-to-everything networks
	Logistics	**Aggregated Distribution**	**Digitised Distribution**
		• Low power and real time embedded system design and algorithm for logistics • Robust and secure V2I sensor network to enable autonomous vehicle to aid in distribution, storage and pick-up within a confined area	Self-manageable autonomous vehicle system to aid in distribution, storage and pick-up across wider area for midnight delivery
	Manufacturing	**Innovation-Led Manufacturing**	**Enhance Portfolio of Profitable Manufacturing Niches**
		To support cottage industry such as the design and development of multi-function sensors and wearables	Autonomous and self-managing senor networks to support advanced robotics and improvement of manufacturing productivity