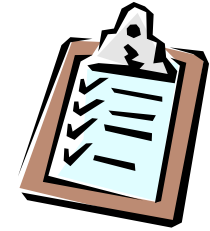智
能
大
廈
科
技

Smart Cities

Ir Dr. Sam C. M. Hui
Department of Mechanical Engineering
The University of Hong Kong
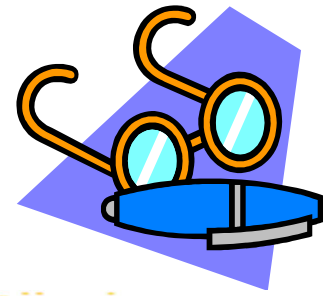E-mail: cmhui@hku.hk

Aug 2025

Contents

- Basic concepts
- Smart city components
- Smart city ecosystem
- IoT-based smart city
- Smart city big data

Basic concepts

- Cities with heavy populations escalate burden on transportation, energy, water, buildings, security & many other things, resulting in poor livability, workability & sustainability

- [Smart City](#) can be defined as "A city that monitors & integrates conditions of all of its critical infrastructures including roads, bridges, tunnels, rails, subways, airports, sea-ports, communications, water & power"
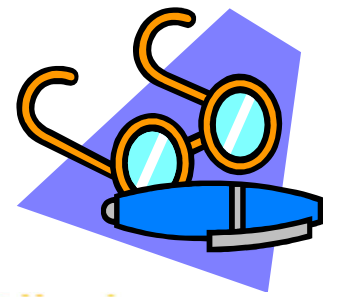
Basic concepts

- A smart city uses information & communications technology (ICT) to enhance its livability, workability & sustainability. [Smart Cities Council]

- A smart city is one that makes optimal use of all the interconnected information available today to better understand & control its operations & optimise the use of limited resources. [IBM]

Smart City concept
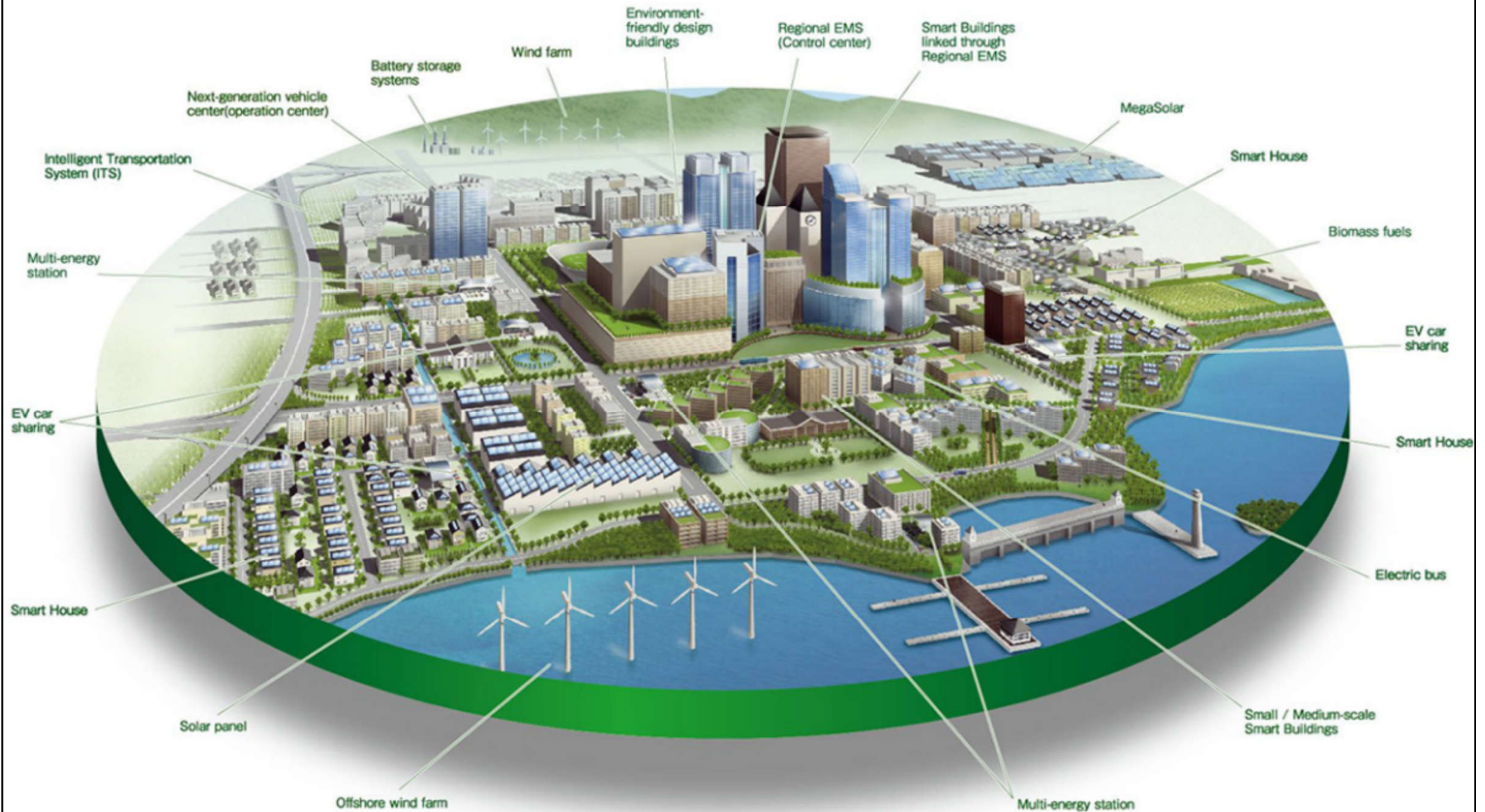
(Source: Vermesan O. & Friess P. (eds.), 2014. *Internet of Things – From Research and Innovation to Market Deployment*, River Publishers, New York. https://doi.org/10.1201/9781003338628)

Basic concepts
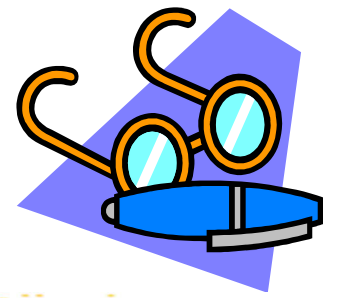
- ## Smart City concept
  - Effective integration of physical, digital & human systems in the built environment to deliver a sustainable, prosperous & inclusive future for its citizens
  - It requires consideration of governance & growth, urban development & infrastructure, the environment & natural resources, society & community
    - Use technologies & intelligence in public management

智慧城市

Examples of smart city requirements
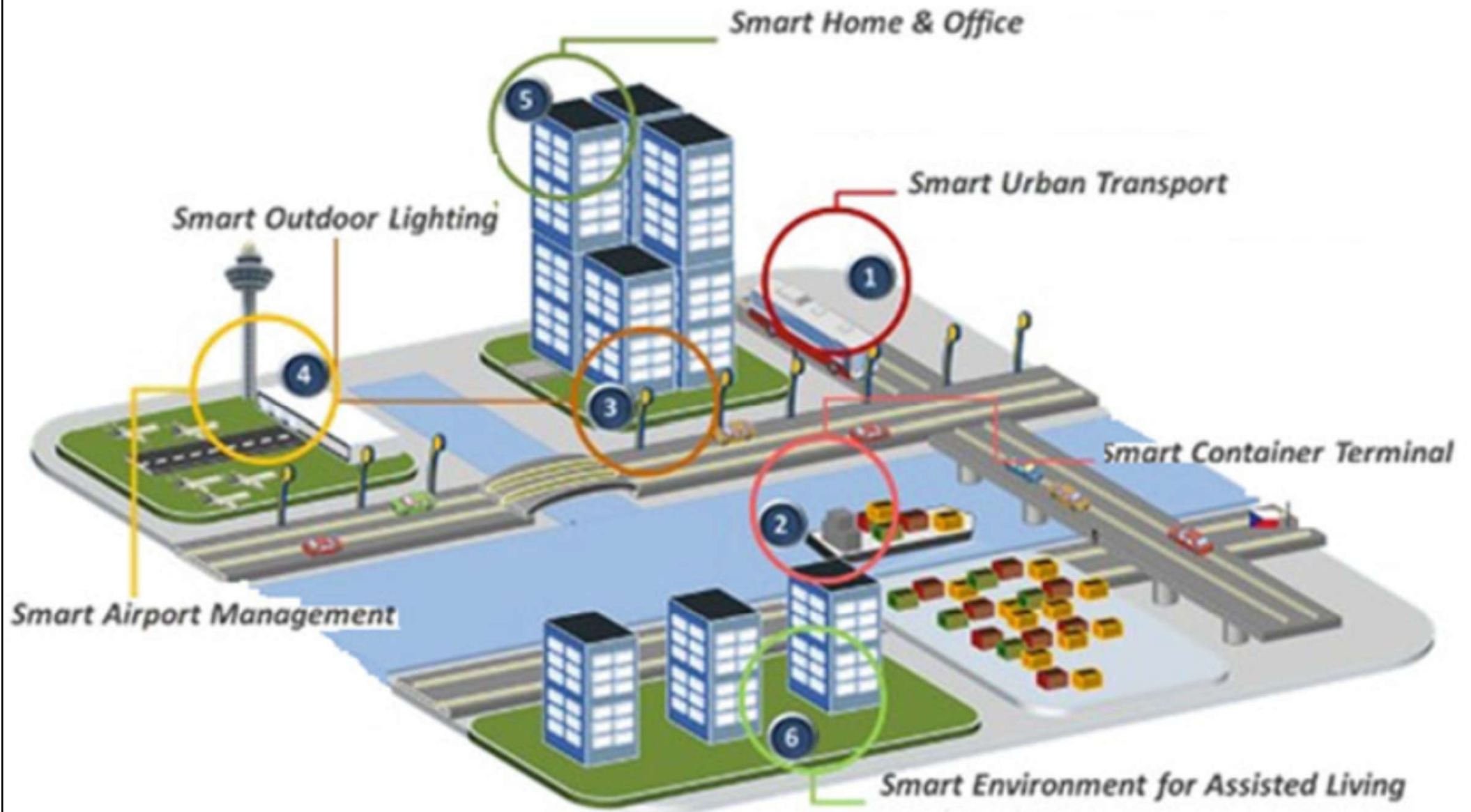
Examples of smart city use cases

(Source: https://www.fusus.com/blog/the-cios-challenge-realizing-the-vision-of-a-smarter-city)

Basic concepts
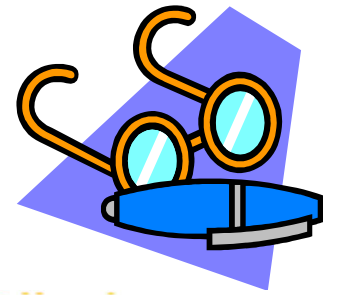
- <u>Smart cities</u> should ensure safe, secure environmentally green & efficient outcomes with all the utility functions e.g. power, water, transportation, etc. are designed, constructed & maintained making use of integrated materials, sensors, electronics & networks which are interfaced with computerized systems comprised of databases, tracking & real-time decision-making algorithms

Application areas of smart city

Smart City
• Smart parking & real-time monitoring • Structural health & vibration monitoring • Noise urban maps & sound monitoring • Traffic congestion monitoring • Smart street lighting • Smart waste management (pay as you throw) • Intelligent transportation systems • Safe city digital video monitoring • Connected learning & sharing electronic resources • Smart irrigation of public spaces • Smart tourism Apps, QR codes & NFC tags

A smart pole installed in smart cities

CommScope Small Cell Pole

- Fiber / Hybrid Fiber Cable
- 4G / 5G low band Radio
- 4G / LTE Antenna
- RF path & connectivity
- 5G mmWave Radio & Antenna
- Public Wi-Fi
- CBRS private LTE
- Microwave backhaul links

Edge Devices IoT

- Software platform – single pane of glass
- Digital signage / kiosk
- Environmental sensors
- Emergency call station
- Speakers
- IoT Gateway/Edge processing
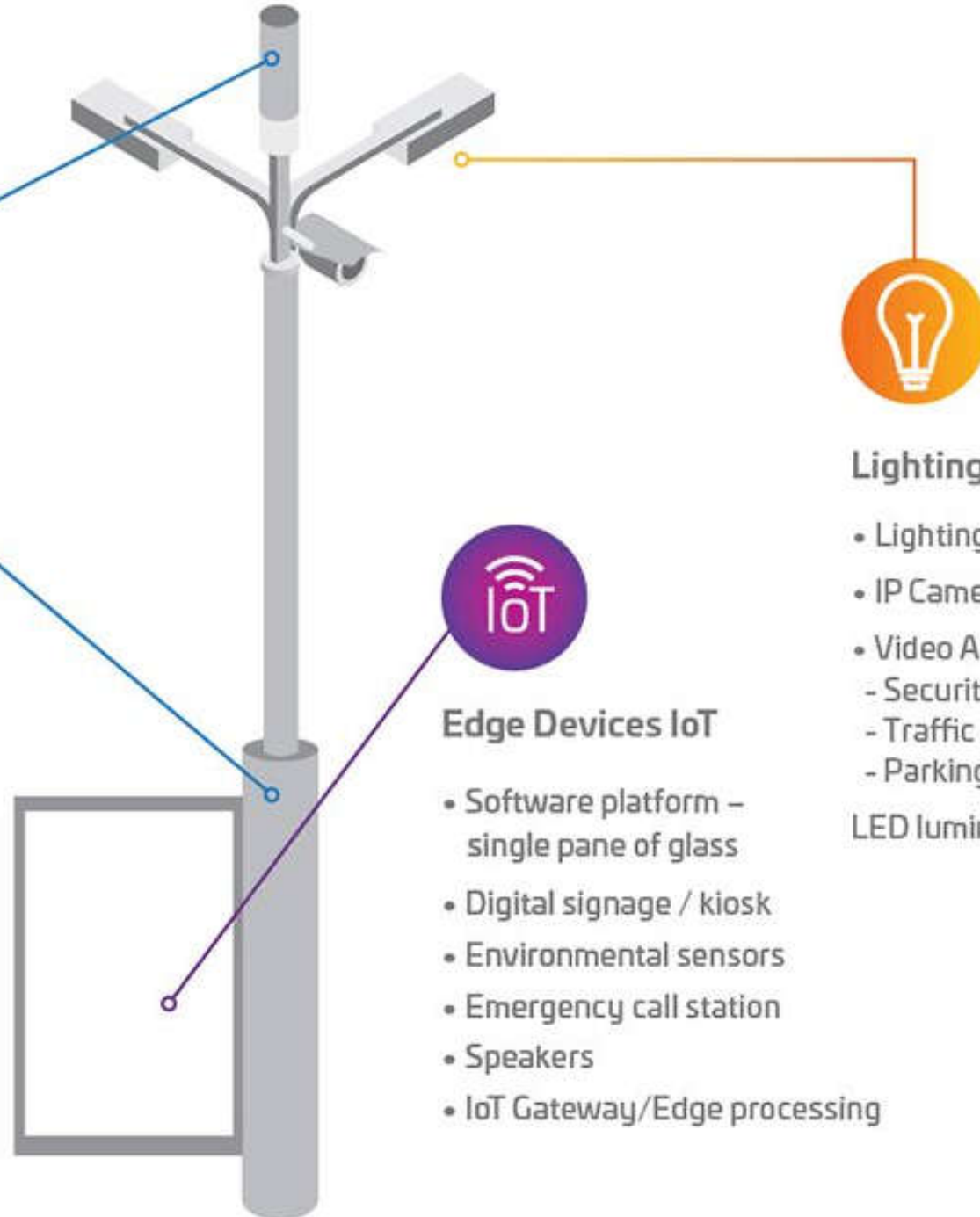
Lighting

- Lighting control system
- IP Camera
- Video Analytics
  - Security
  - Traffic / Pedestrian
  - Parking

LED luminaire

(Source: https://www.commscope.com/insights/the-enterprise-source/smart-spaces-the-fact-file/)

Smart transportation layout
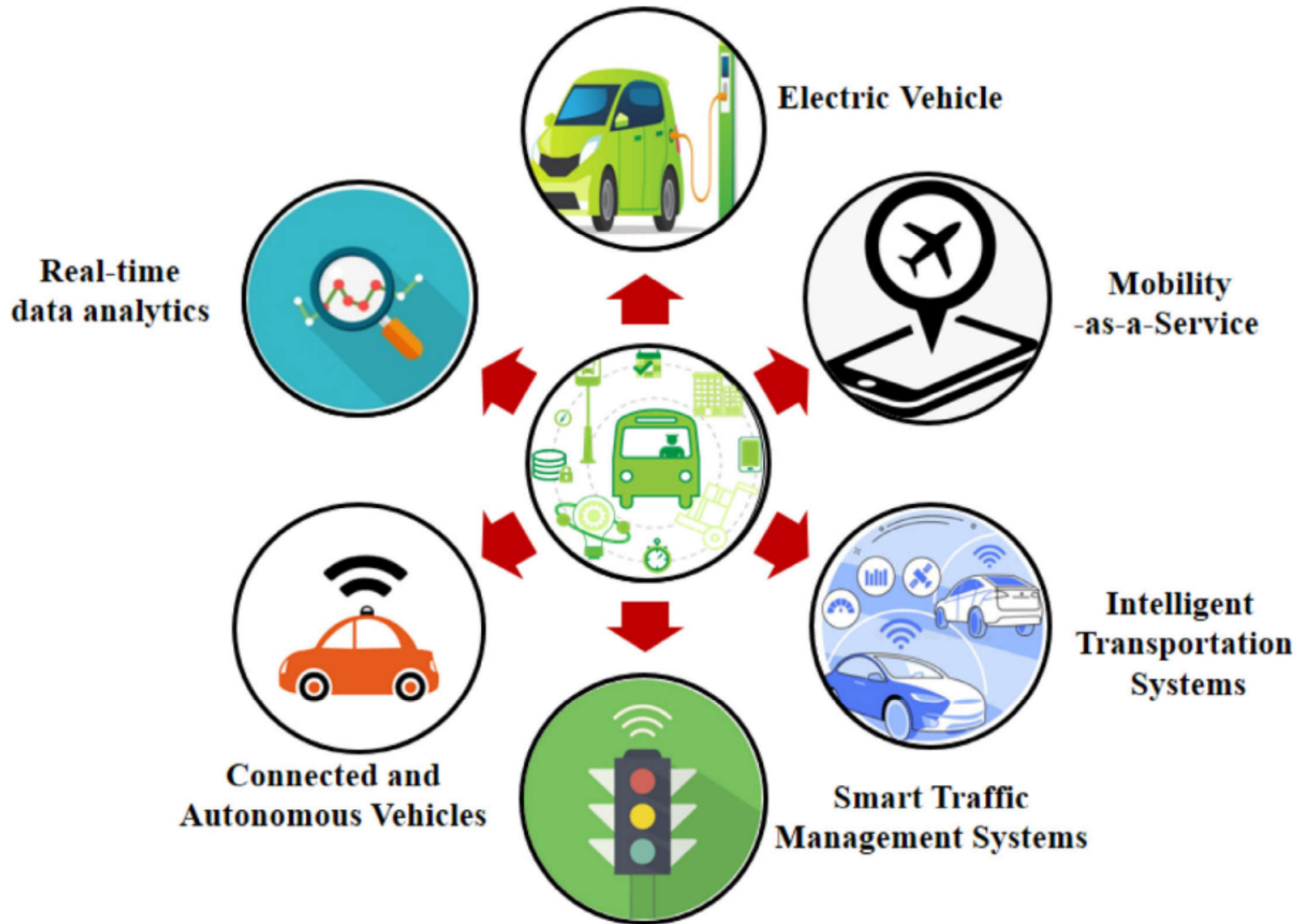
Electric Vehicle

Mobility -as-a-Service

Real-time data analytics

Connected and Autonomous Vehicles

Intelligent Transportation Systems

Smart Traffic Management Systems

Digital retail store supported by flexible, hyper-local, real-time sensor fusion & big data analytics

Cloud Platform
Central Compute & Big Data Repository, Additional Big Data; Ecom, Mobile, Social, etc.

Fog Platform
Local Data, Events, Rules, Analytics, Visualization

IR Motion

Door Hinges

Gesture Recognition

Wi-Fi / Location

Video Cameras

Digital Signage

Associate Mobile

Wi-Fi Badge

Customer Mobile

Shelf Weight Sensors

Wi-Fi Tags

Parking Space Sensors

Weight Mats
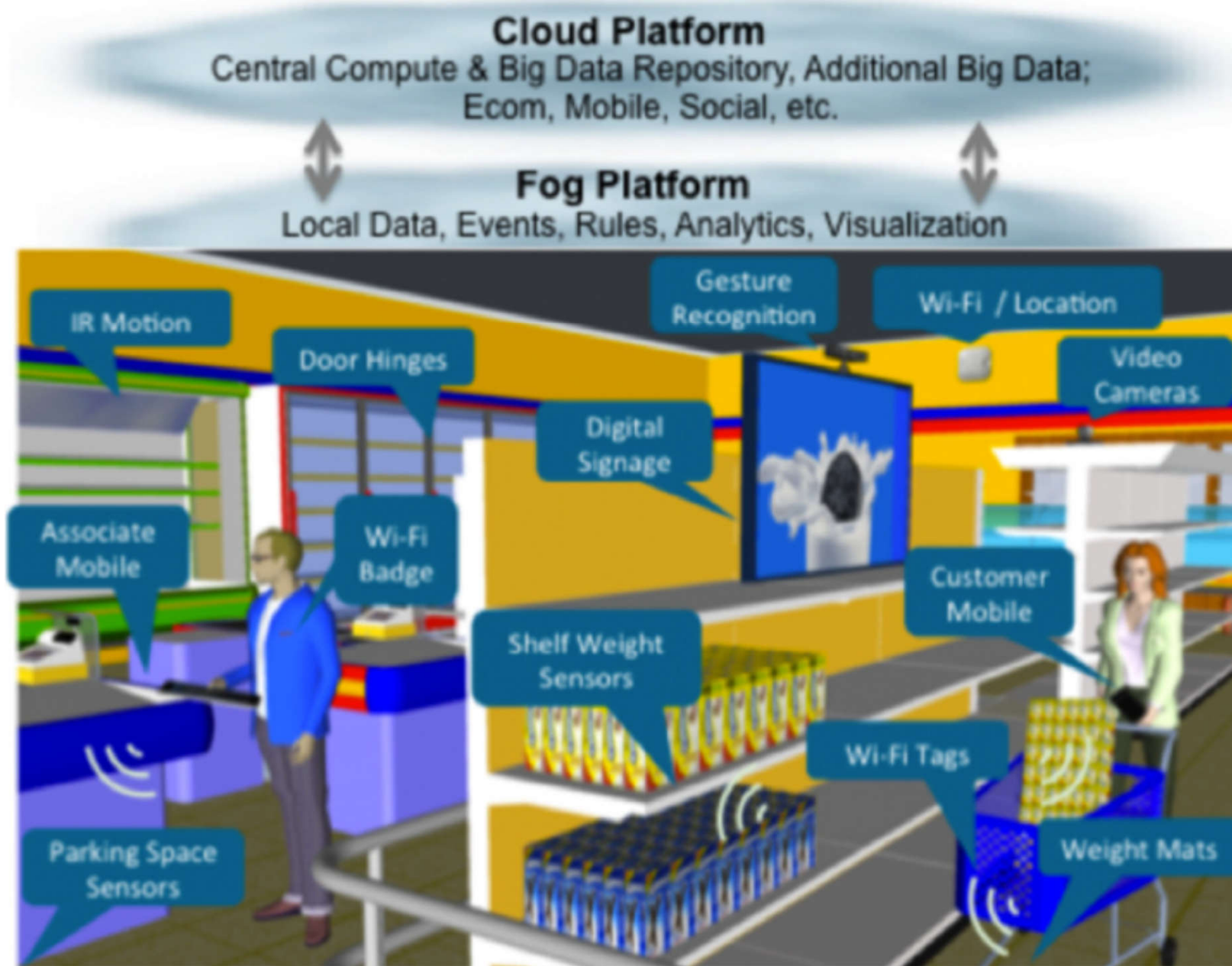
Applications & services within a smart city

Smart car, smart parking, smart traffic signals, smart roads, smart city transportation

Smart agriculture, smart retail, smart payment systems, smart offices and buildings, smart grid, smart manufacturing

Smart home, smart TV, smart AC, smart in-house lighting, smart refrigerator, smart health monitoring appliances

Smart city (applications and services)

Smart municipal governance, smart wastebins, smart surveillance, smart metering, smart gas and water supply and leakage detection

Smart street lights, smart education, smart city navigation panels, smart healthcare services, smart public toilets

Smart pollution monitoring, smart recycling, smart town planning, energy and disaster management, smart waste management

Smart city services & functions
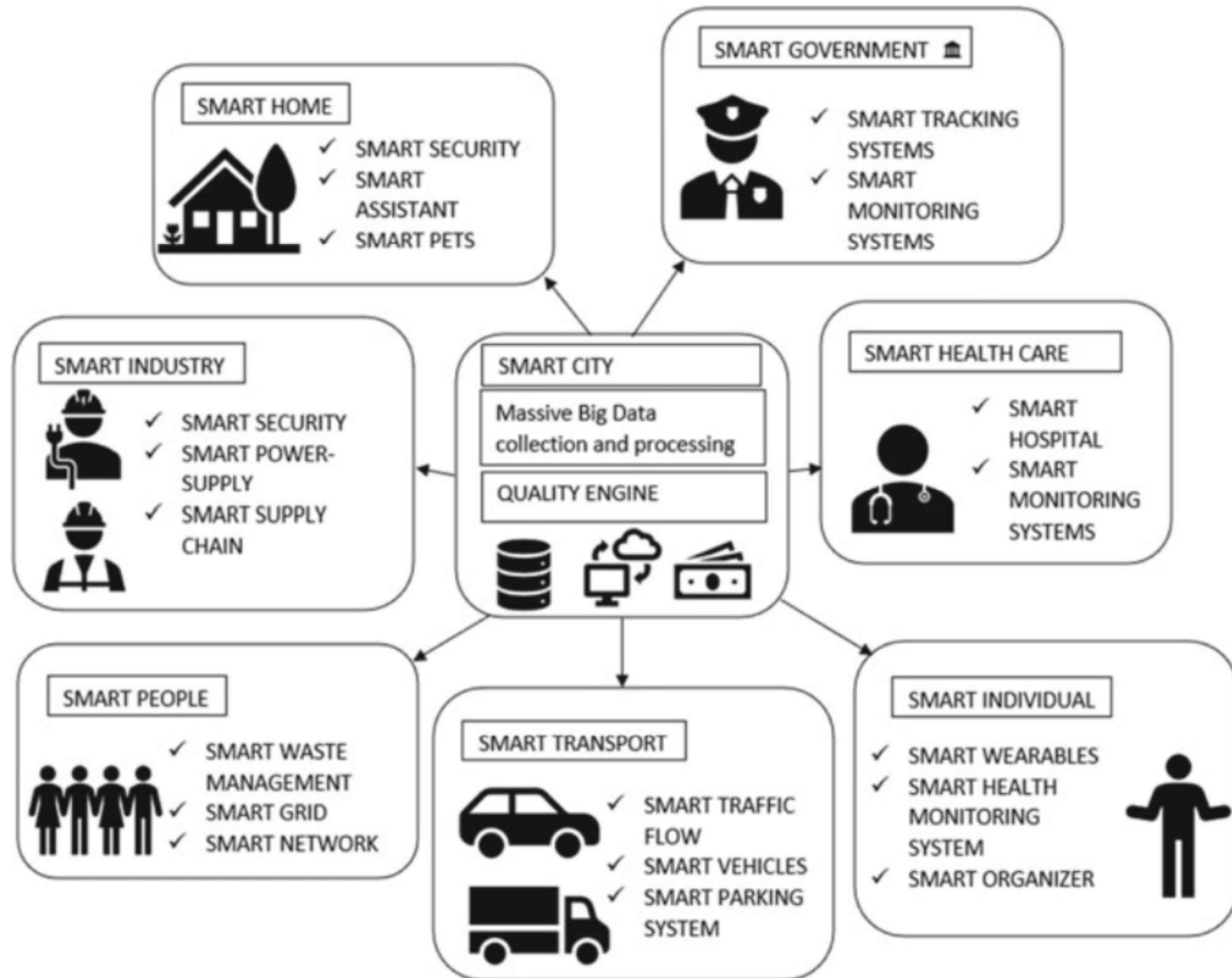
Smart city components

- Core elements of a smart city:
    - Good governance (e-Governance & citizen)
    - Safety & security of citizens
    - Sustainable environment
    - Adequate water & electricity supply, sanitation
    - Efficient urban mobility & public transport
    - Affordable housing (especially for the poor)
    - Robust IT connectivity & digitalization
    - Health & education

Key components of a smart city & related aspects

(Source: https://www.intechopen.com/chapters/74934)
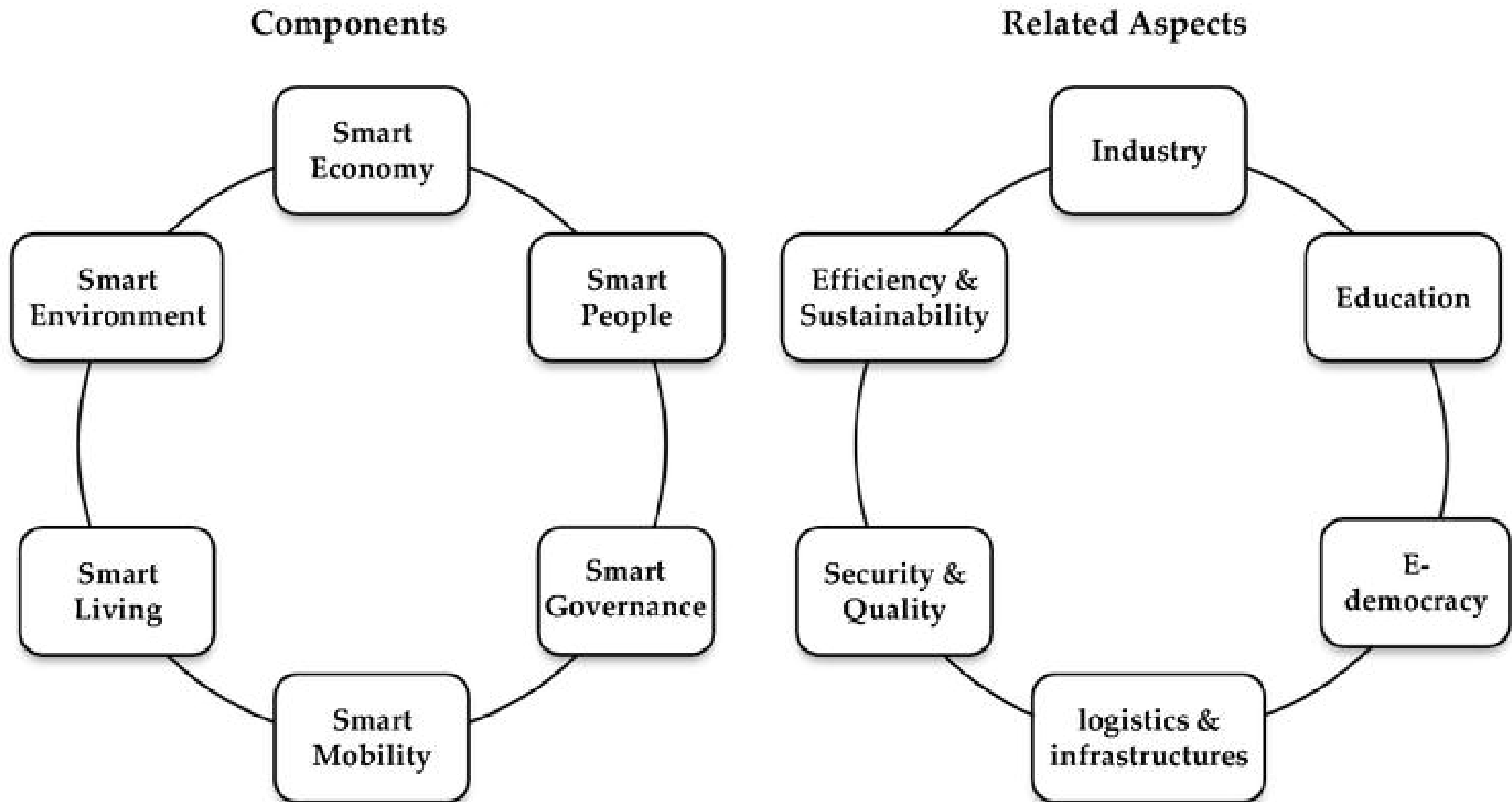
Description of smart city components

Components	Description
Smart Economy	E-economy which is associated with the presence of industries in ICT or employing ICT in production processes.
Smart People	Refers to people possessing creativity, diversity & education
Smart Governance	Various stakeholders are engaged in decision making & public services
Smart Mobility	Refers to the use of ICT in modern transport technologies to improve urban traffic
Smart Living	The smart people factor comprises various aspects, such as affinity to lifelong learning, social & ethnic plurality, flexibility, creativity, cosmopolitanism, open-mindedness & participation in public life
Smart Environment	Refers to efficiency and sustainability of environment, while smart technologies are in use

(Source: https://www.intechopen.com/chapters/74934)

Smart diamond to define smart city
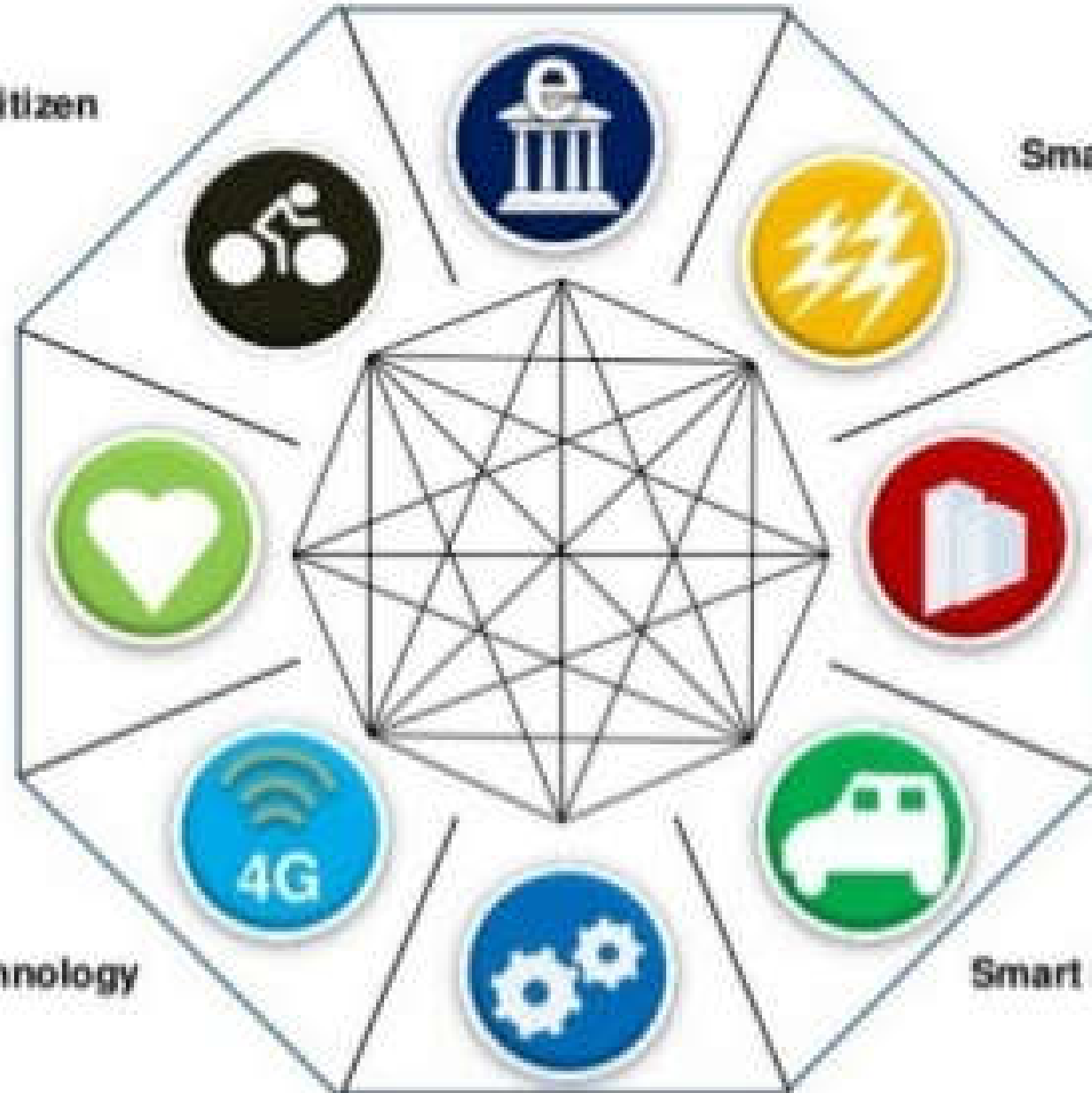
Example of smart city components
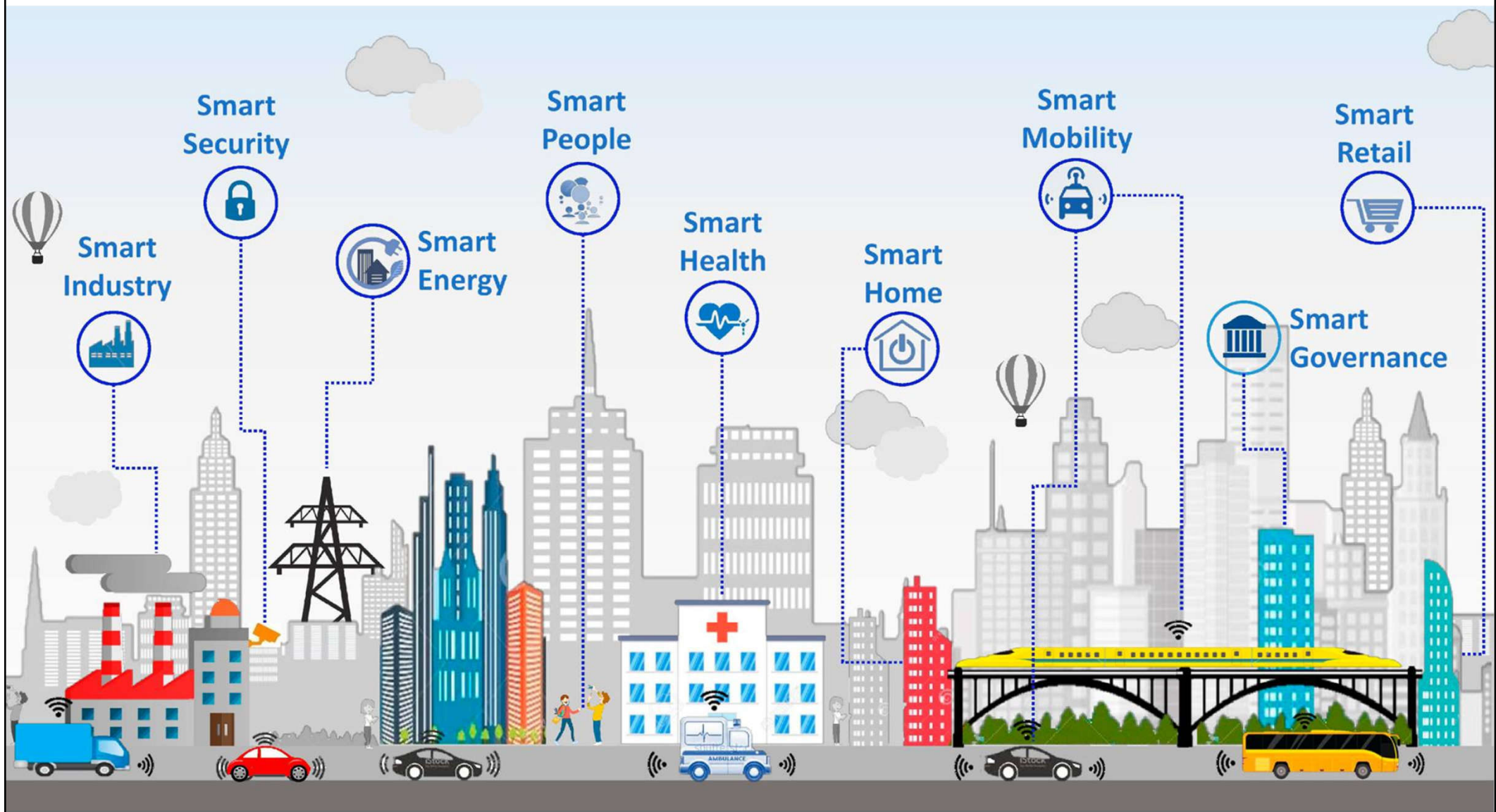
Smart city components & the connections among them
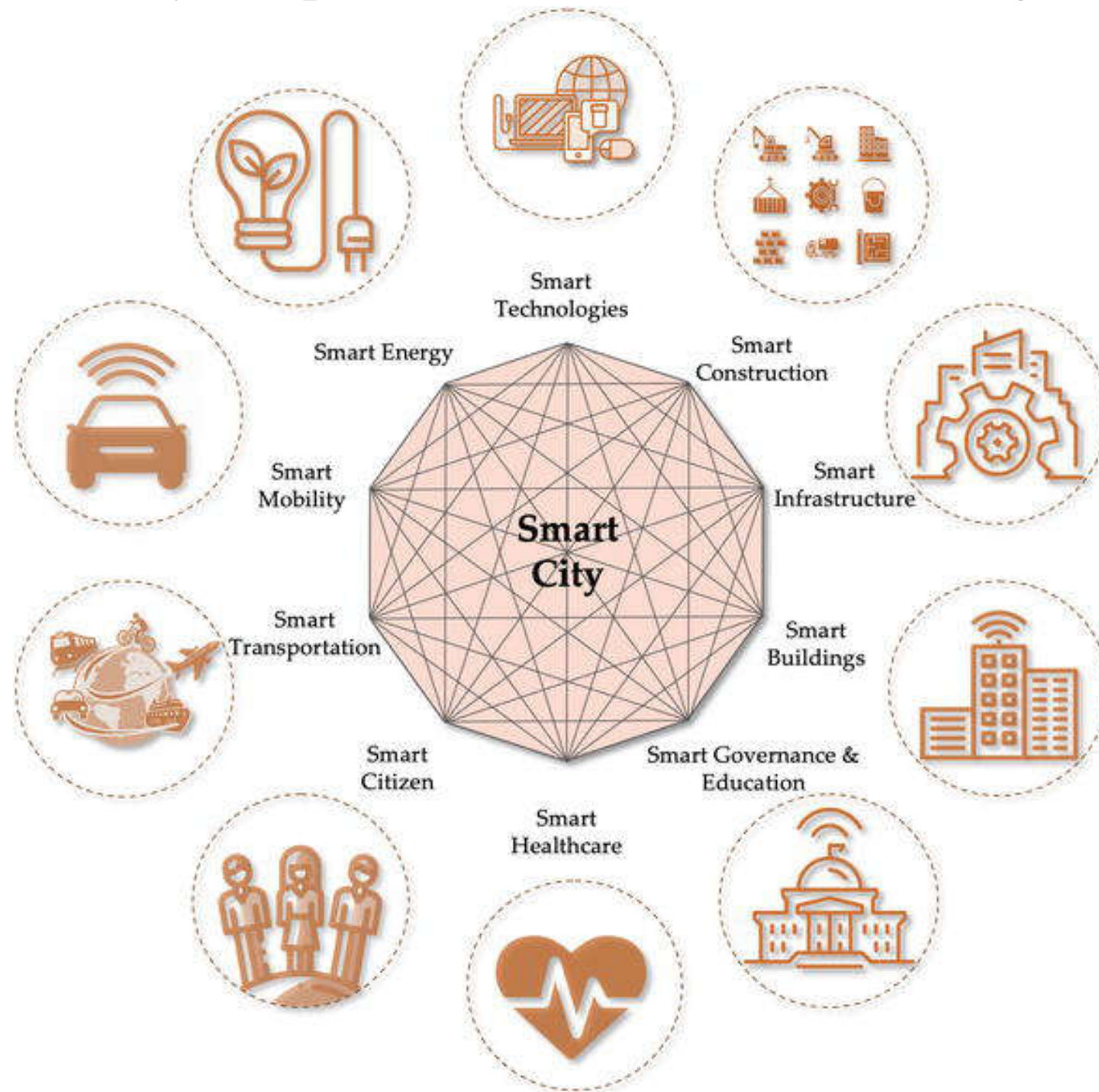
Application examples of smart city components

Smart Buildings	Smart Health	Smart Living
Perimeter access control Liquid detection Indoor climate control Intelligent thermostat Intelligent fire alarm system Intrusion detection systems Motion detection Art & goods preservation Residential irrigation	Fall detection Aging people monitoring Medical fridges control Sportsmen care monitoring Patient surveillance Chronic disease management Measure ultraviolet radiation Hygienic hand control Sleep control w/ sensors Dental health device & app	Intelligent shopping Smart home appliances Remote control appliances Energy & water monitoring Weather station Fuel gas monitoring Safety monitoring (e.g. baby) Smart jewelry
Smart Transport	**Smart Energy**	**Smart Enviro. Monitoring**
Automatic vehicle payment Electric vehicle charging Vehicle auto-diagnosis Management of cars Fleet tracking Shipment conditions Item location Storage detection	Smart grid management Photovoltaic installations Wind turbines Water flow & transportation Nuclear radiation alerts Power supply control	Forest fire detection Air pollution control Prevent landslide/avalanche Earthquake early detection Protecting wildlife Meteorological station Marine/Coastal surveillance

Basic concepts & requirements of smart city
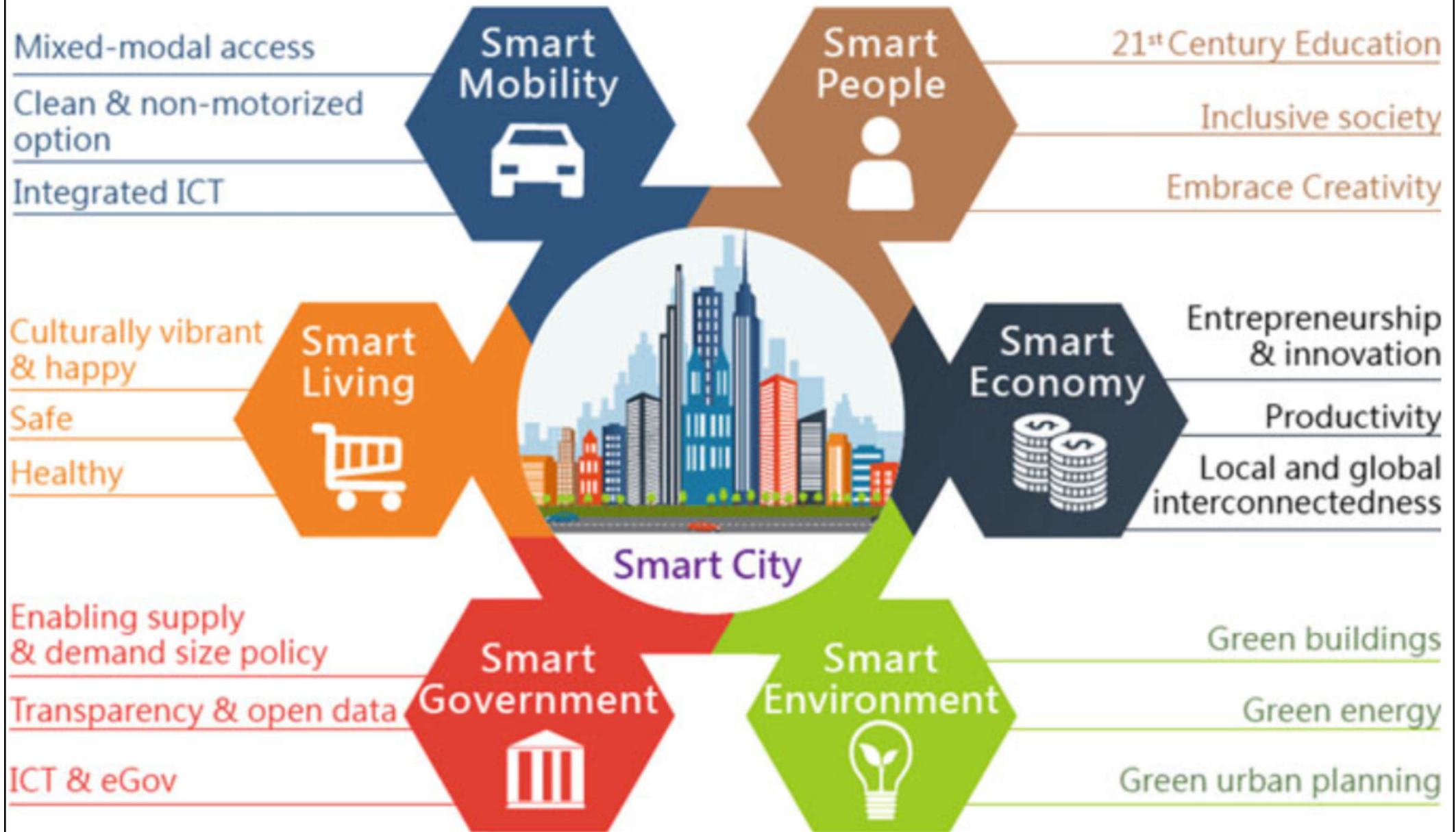
Smart Mobility
- Mixed-modal access
- Clean & non-motorized option
- Integrated ICT

Smart People
- 21st Century Education
- Inclusive society
- Embrace Creativity

Smart Living
- Culturally vibrant & happy
- Safe
- Healthy

Smart Economy
- Entrepreneurship & innovation
- Productivity
- Local and global interconnectedness

Smart Government
- Enabling supply & demand size policy
- Transparency & open data
- ICT & eGov

Smart Environment
- Green buildings
- Green energy
- Green urban planning

Smart City

Smart solutions & infrastructure elements for smart cities

E-Governance and Citizen Services

1. Public Information, Grievance Redressal
2. Electronic Service Delivery
3. Citizen Engagement
4. Citizens - City's Eyes and Ears
5. Video Crime Monitoring

Waste Management

6. Waste to Energy & fuel
7. Waste to Compost
8. Waste Water to be Treated
9. Recycling and Reduction of C&D Waste

Water Management

10. Smart Meters & Management
11. Leakage Identification, Preventive Maint.
12. Water Quality Monitoring

Energy Management

13. Smart Meters & Management
14. Renewable Sources of Energy
15. Energy Efficient & Green Buildings

Urban Mobility

16. Smart Parking
17. Intelligent Traffic Management
18. Integrated Multi-Modal Transport

Others

19. Tele-Medicine & Tele Education
20. Incubation/Trade Facilitation Centers
21. Skill Development Centers

(Source: http://bareillysmartcity.in/what-is-smart-city.html)

Smart city ecosystem

- People interacting with urban services & employing digital services, energy, materials & funding to promote economic growth & provide a better quality of life
  - Make strategic application of digital infrastructure & services related to ICT with urban management & planning to meet the economic & social requirements of society
  - Use connected devices to monitor & manage their streets & public spaces

Conceptual illustration of an operational smart city
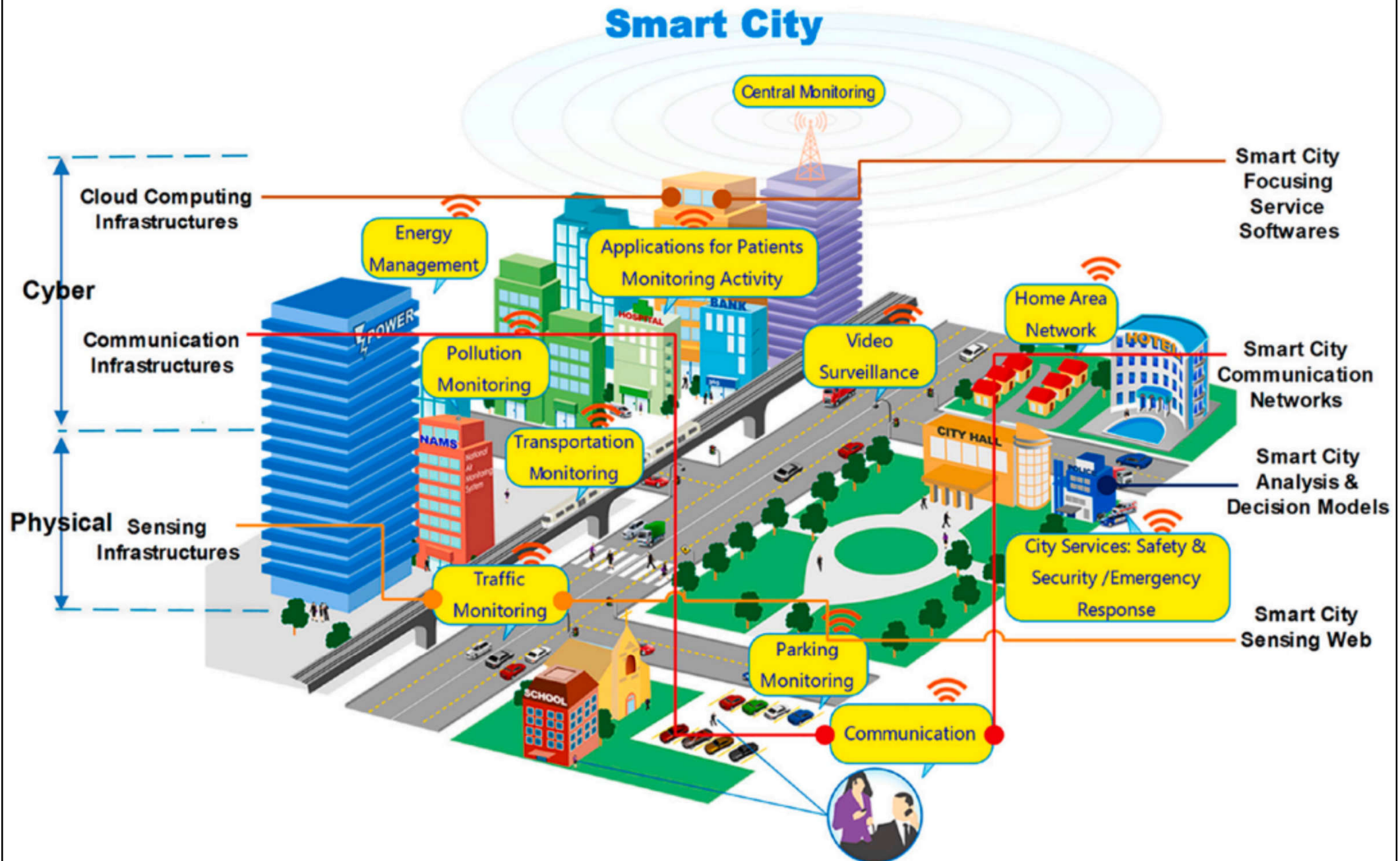
(Source: Baduge S. K., Thilakarathna S., Perera J. S., Arashpour M., Sharafi P., Teodosio B., Shringi A. & Mendis P., 2022. Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications, *Automation in Construction*, 141: 104440. https://doi.org/10.1016/j.autcon.2022.104440)

Smart city ecosystem

- Objectives of smart city ecosystem:
    - 1. Government efficiency
    - 2. Economic development (business, productivity)
    - 3. Sustainability (environmental, energy, etc.)
    - 4. Public safety (protect from crime, disasters)
    - 5. Health & wellness (mental/physical, social care)
    - 6. Quality of life (living standard, satisfaction)
    - 7. Mobility (transportation, traffic management)
    - 8. Resilience (continuity of services & operations)

Conceptual framework of smart building integration into a smart city

Functional Integration

SMART CITY

- Improved Efficiency, Resilience, and Environmental sustainability of city performance
- Enhanced urban living for Citizens, Customers, Visitors

SMART BUILDING

Smart energy, smart mobility, smart water, smart security, and smart waste management

Smart Services & Smart business model
(Intelligent transportation , smart energy management solutions, smart environmental monitoring, citizen engagement platforms, etc.)

Shared resources, data exchange, and coordinated services to enhance the efficiency and effectiveness of the entire city's infrastructure

Data Integration

Central repository for storing, processing, and analyzing, and employing the vast amount of data city's infrastructure generates.

Data layer of smart city

Data Layer
(Data from sensors, Smart Meter and other devices that collect data on energy consumption, Traffic flow, Waste level, Air quality, and other relevant parameters)

Data layer of smart building

Enables Information exchange, optimization, coordination, and synchronization of building operations with the city's performance

Physical Integration

Upgraded legacy infrastructure of a smart city with sensors, smart meters, IoT devices, etc.

Infrastructure
Physical components energy, transportation networks, safety and security system, communication infrastructure, waste management

Building infrastructure enabling to connect to the infrastructure of the smart city

Smart city ecosystem

- <u>Smart buildings</u> are connected & can provide a platform for multiple services that help to enhance the development of the <u>smart city</u>

  - For example, the smart grid is the link between the smart building and the smart city

- <u>Smart society</u> is one dimension of the smart city, focusing on humans as city elements

  - Within the Smart City, human interaction moves towards a socio-technical ecosystem, where the physical & virtual dimensions converge

From smart building & smart city to smart society
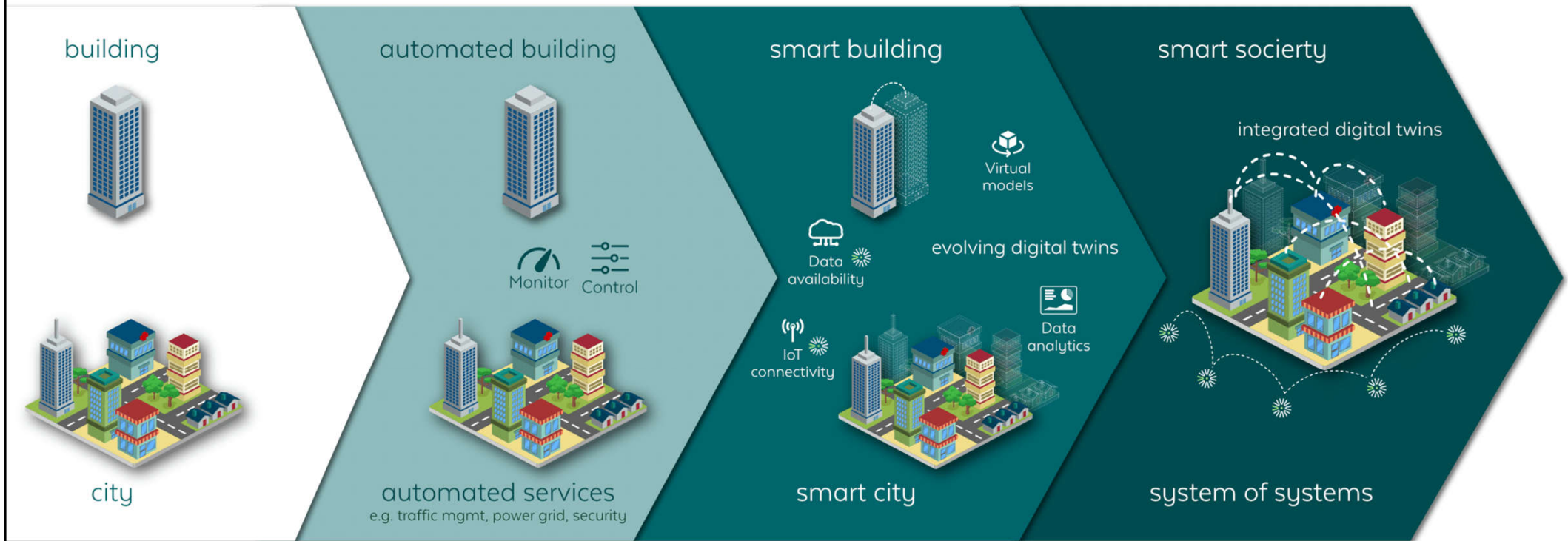
Factors shaping Hong Kong's ongoing development as a smart, sustainable & connected city

Global trends

UN Sustainable development goals

Ageing Population

Resource Scarcity

Individual Empowerment

Global Climate Change

Sustainability & Resources

Innovation & Technology as an enabler

People

- Amenity & Liveability
- Resource and waste management
- Climate change readiness
- Land use and urban redevelopment

- Addressing income inequality
- Affordability of housing
- Transportation & Mobility
- Building a future-focused workforce
- Healthcare and elderly care

Factors that shape Hong Kong's development

- Economic Growth
- R&D and Direct Investment
- Employment and Job Creation
- Future-focused policy and regulation

Economic interconnectivity

Geopolitical Climate

Economic and geopolitical factors

Capital Markets and Investment Trends

Source: KPMG China Smart City Group

(Source: KPMG, 2021. *Hong Kong's Connected Future Report 2021- Building a smarter and greener city*, KPMG, Hong Kong. https://assets.kpmg/content/dam/kpmg/cn/pdf/en/2022/01/hong-kong-sconnnected-future.pdf)
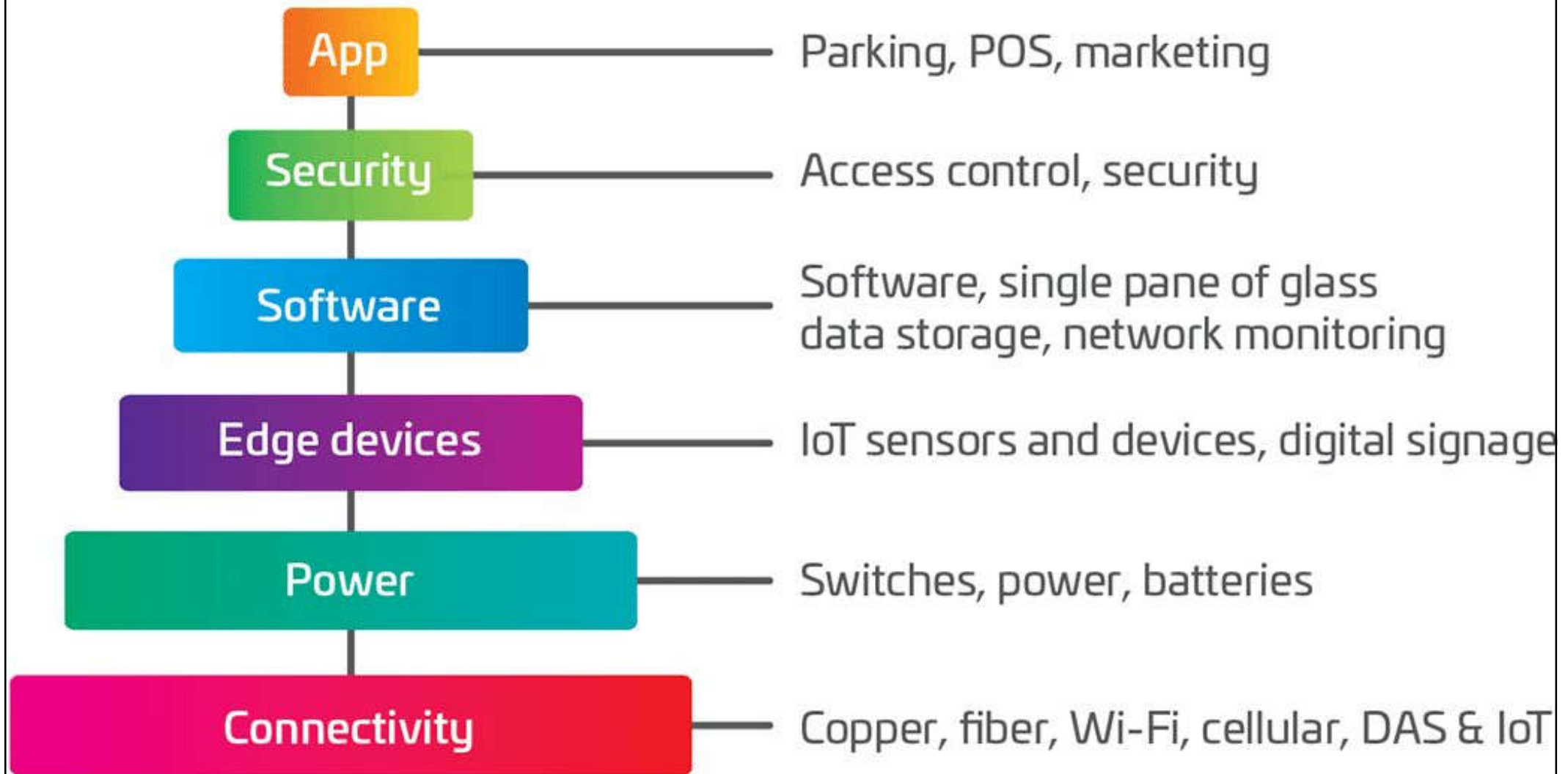
Smart city ecosystem

- 3 fundamental layers of smart city operations:
  - 1. <u>Technological Layer</u>: A large number of sensors & connected IoT devices used to provide a wide range of services
  - 2. <u>Dedicated Applications</u>: Information systems used by city officials & citizens to improve city operations (e.g. transport, healthcare, utilities)
  - 3. <u>Application Usage</u>: Implementation & usage of the applications inside the city by designated users

Smart city ecosystem

- How smart cities work?

  - 1. <u>Collection</u> – Smart sensors gather real-time data

  - 2. <u>Analysis</u> – The data is analysed to gain insights into the operation of city services & operations

  - 3. <u>Communication</u> – The results of the data analysis are communicated to decision makers

  - 4. <u>Action</u> – Action is taken to improve operations, manage assets & improve the quality of city life for the residents

Different layers of infrastructure for smart cities

App — Parking, POS, marketing

Security — Access control, security

Software — Software, single pane of glass data storage, network monitoring

Edge devices — IoT sensors and devices, digital signage

Power — Switches, power, batteries

Connectivity — Copper, fiber, Wi-Fi, cellular, DAS & IoT
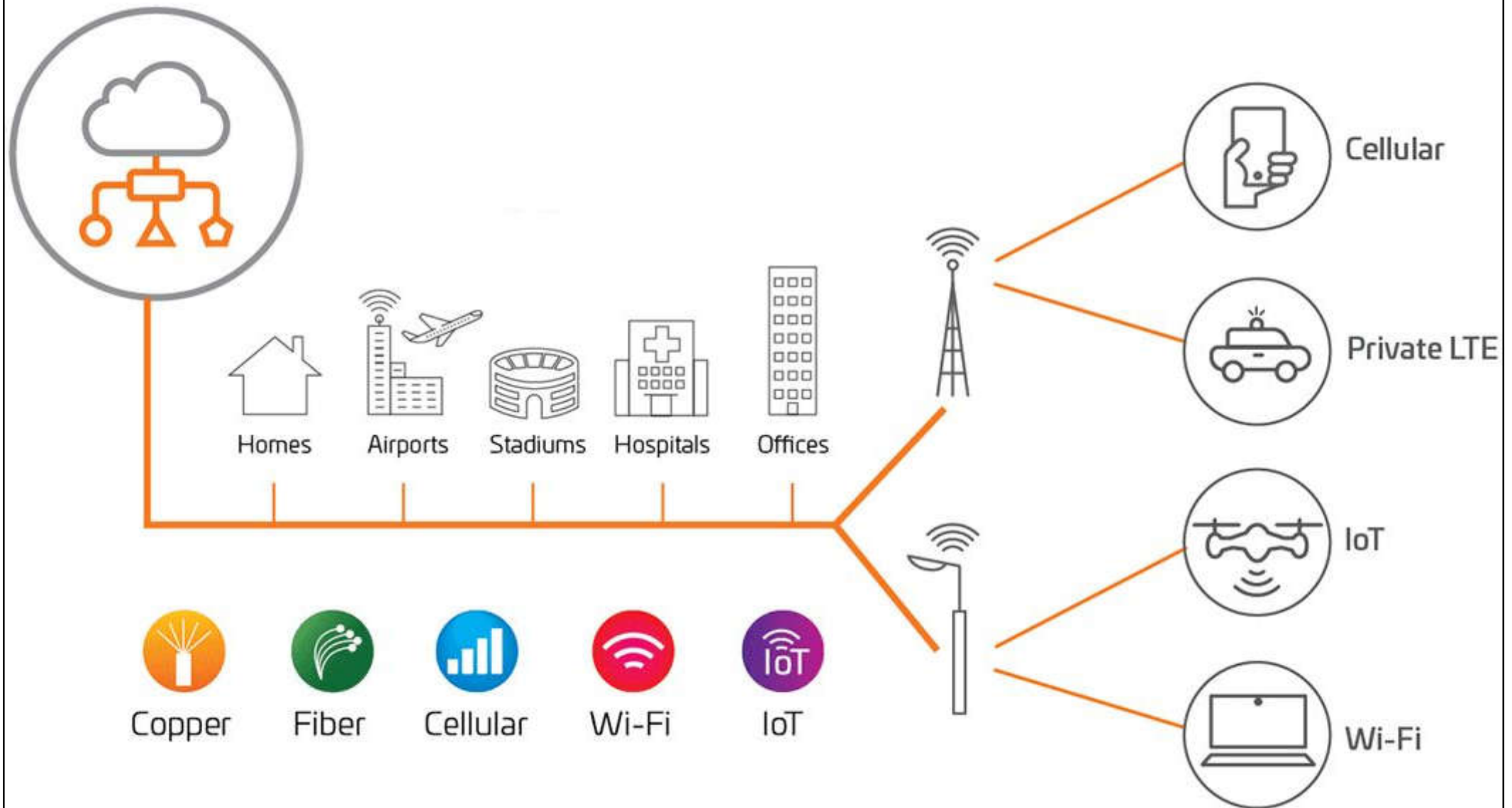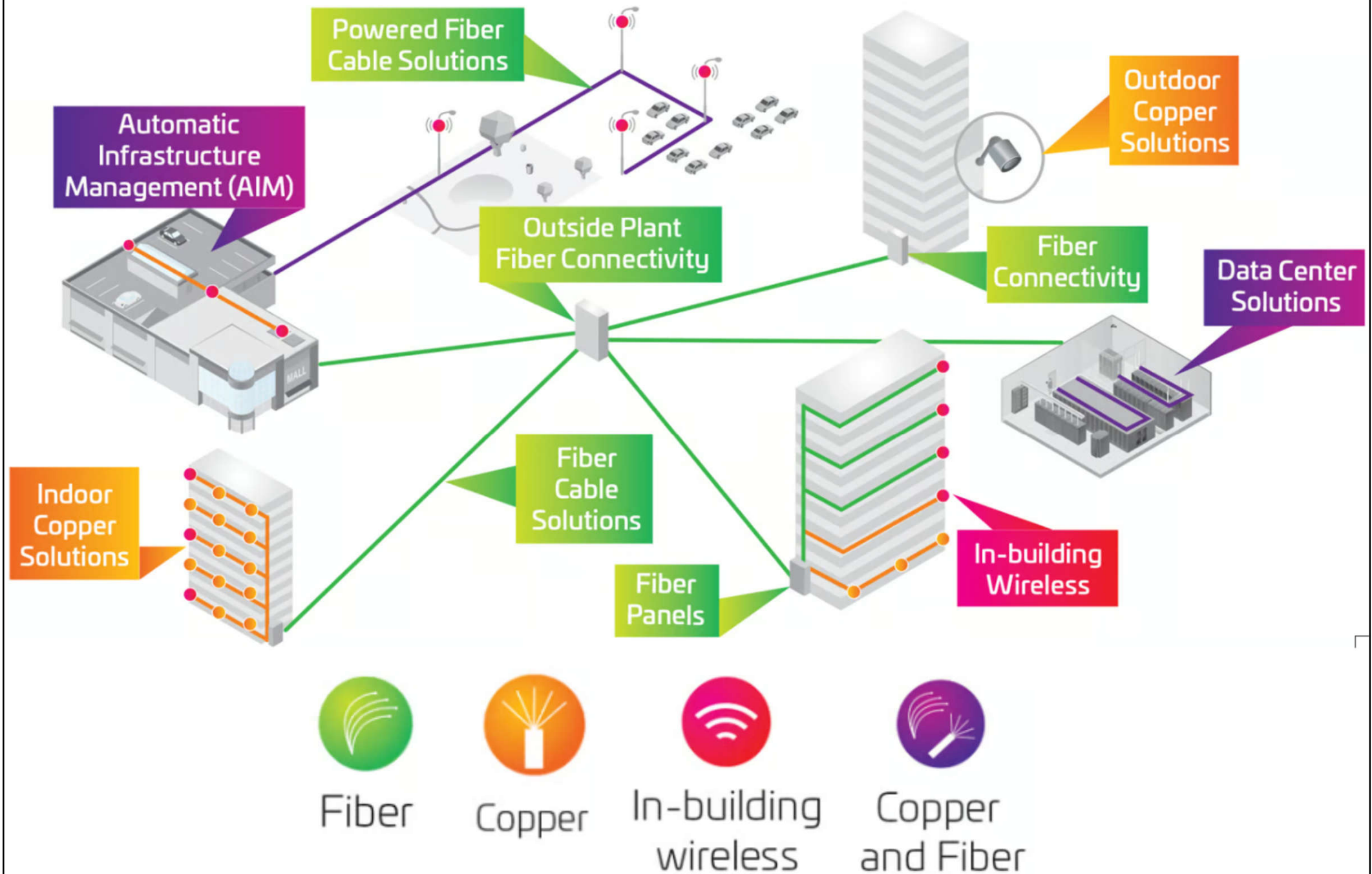
Smart city ecosystem

- Technologies used in smart cities:
  - Data acquisition with sensors & IoT
  - Network & communication technology
  - Cloud computing & data centres
  - Edge computing (at the device end)
  - Software-defined networks (SDN)
  - Block chain (retains authentication & security)
  - Big data (analysis & systematic processing)
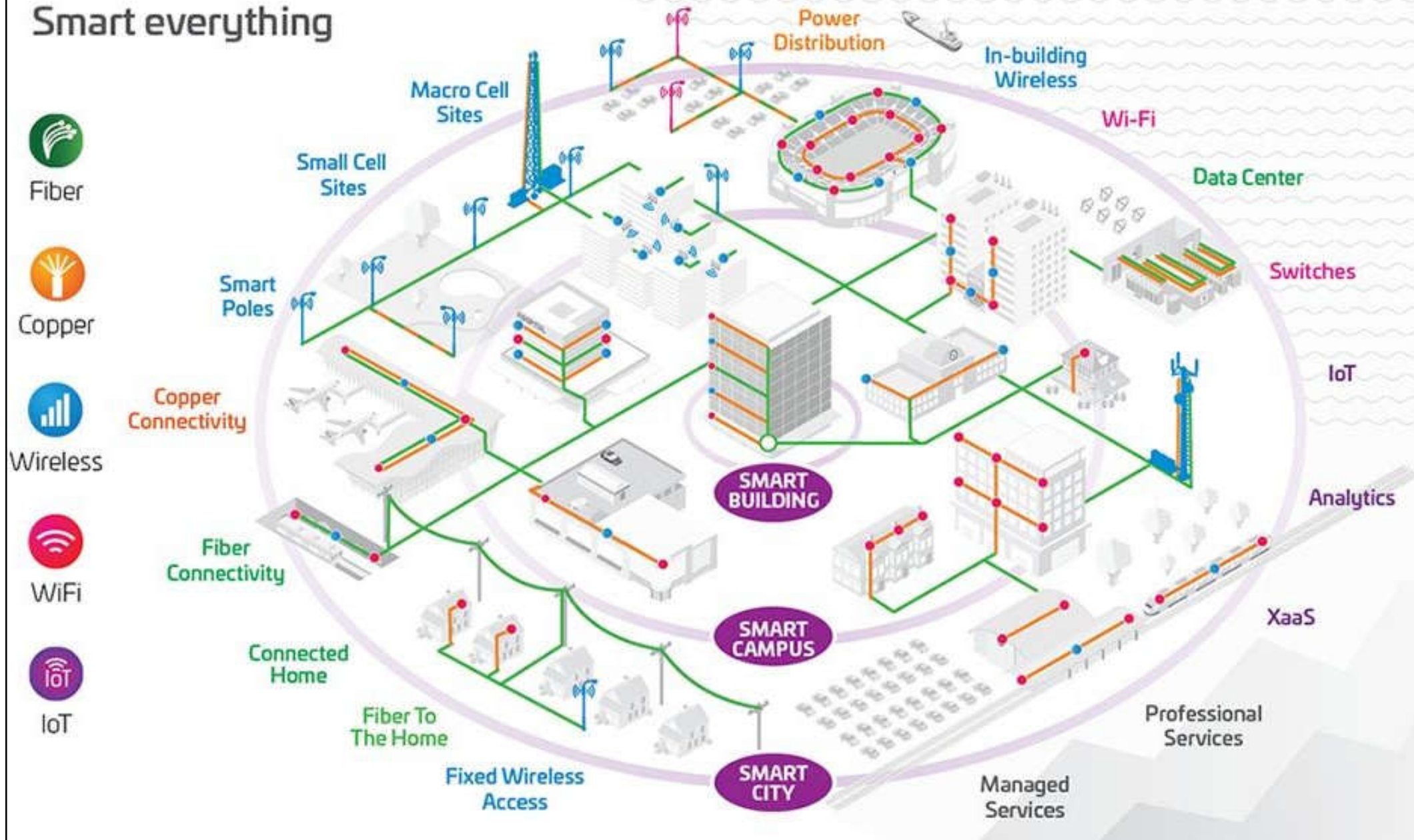 - Artificial intelligence & machine learning

Our connected world & urban environment for smart cities with different connectivity methods

Smart campus network

Powered Fiber Cable Solutions

Automatic Infrastructure Management (AIM)

Outdoor Copper Solutions

Outside Plant Fiber Connectivity

Fiber Connectivity

Data Center Solutions

Indoor Copper Solutions

Fiber Cable Solutions

In-building Wireless

Fiber Panels

Fiber   Copper   In-building wireless   Copper and Fiber

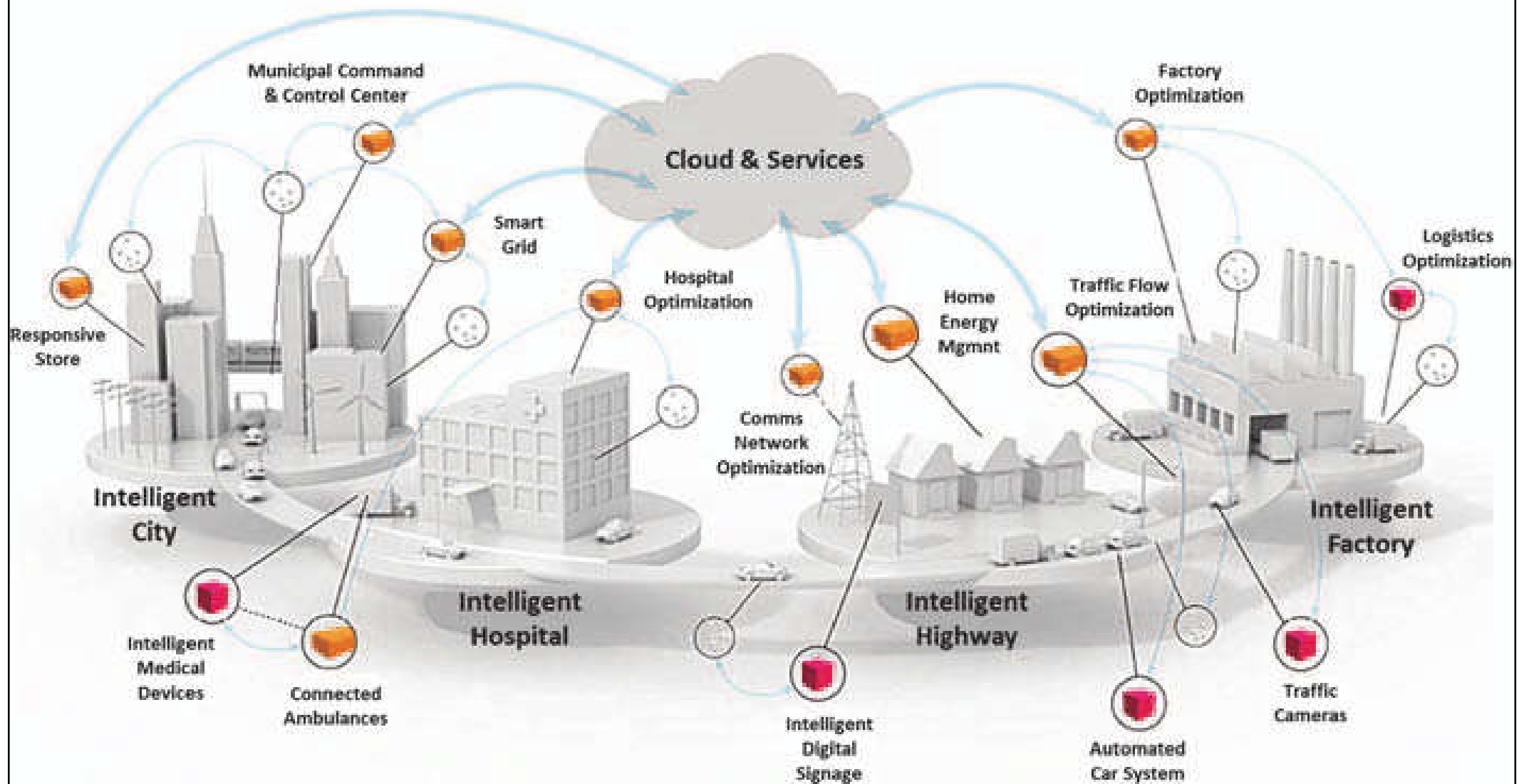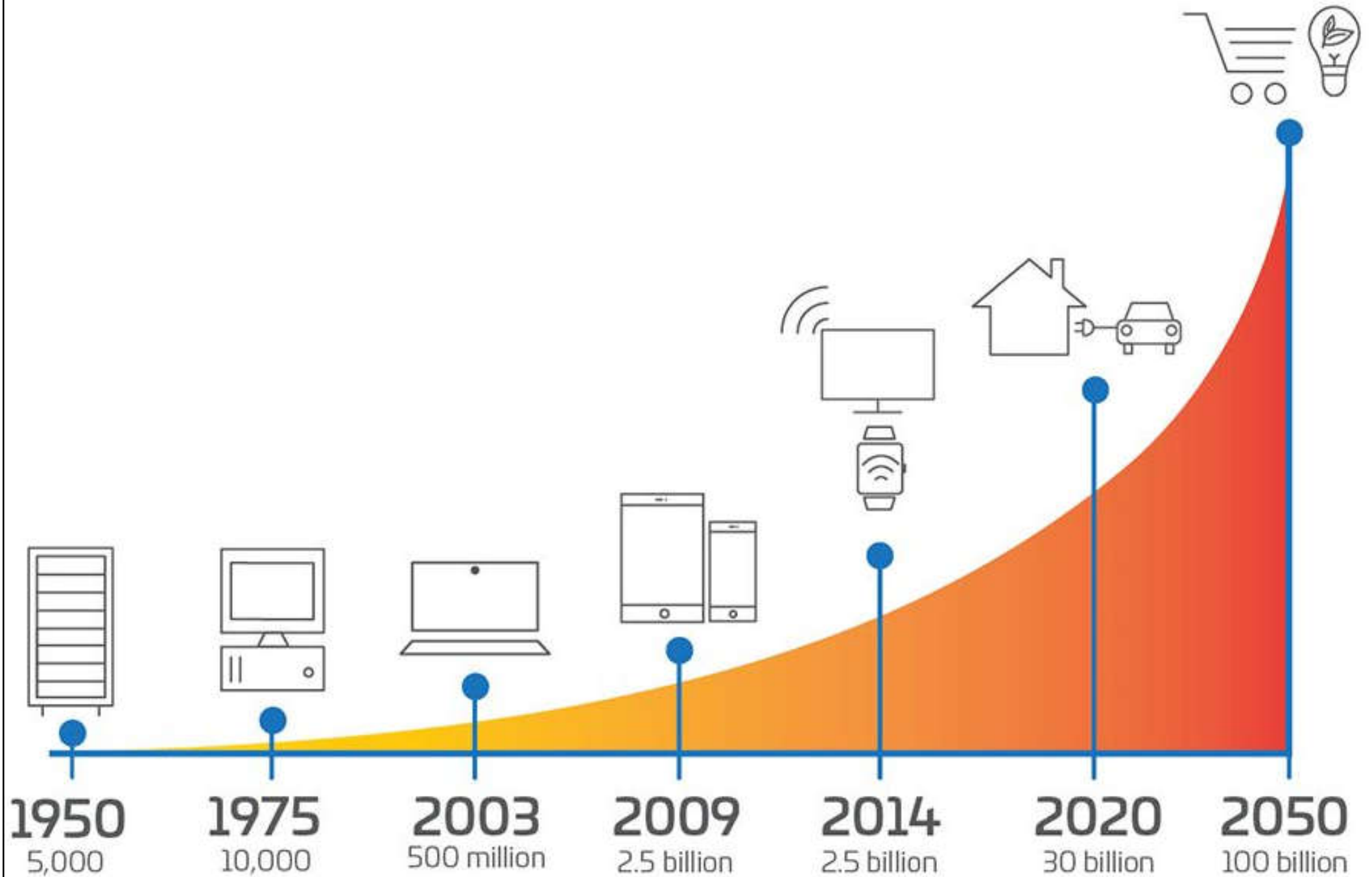# From smart building to smart campus to smart city

IoT-based smart city

- Internet of City Things (IoCT)
  - Smart cities use IoT devices (e.g. sensors, lights & meters) to collect & analyze data
  - The cities then use this data to improve infrastructure, public utilities & services, etc.
  - Using IoT to create smarter, more connected cities requires a reliable & efficient network infrastructure, e.g. cellular licensed networks like 4G, 5G, or LTE-M, or unlicensed networks like Wi-Fi or LoRaWAN

Internet of Things (IoT): Intelligent systems framework

Expected adoption growth of IoT devices

1950	1975	2003	2009	2014	2020	2050
5,000	10,000	500 million	2.5 billion	2.5 billion	30 billion	100 billion

Common Internet of Things (IoT) communication protocols for smart buildings & smart cities

The IoT: different services, technologies, meanings for everyone
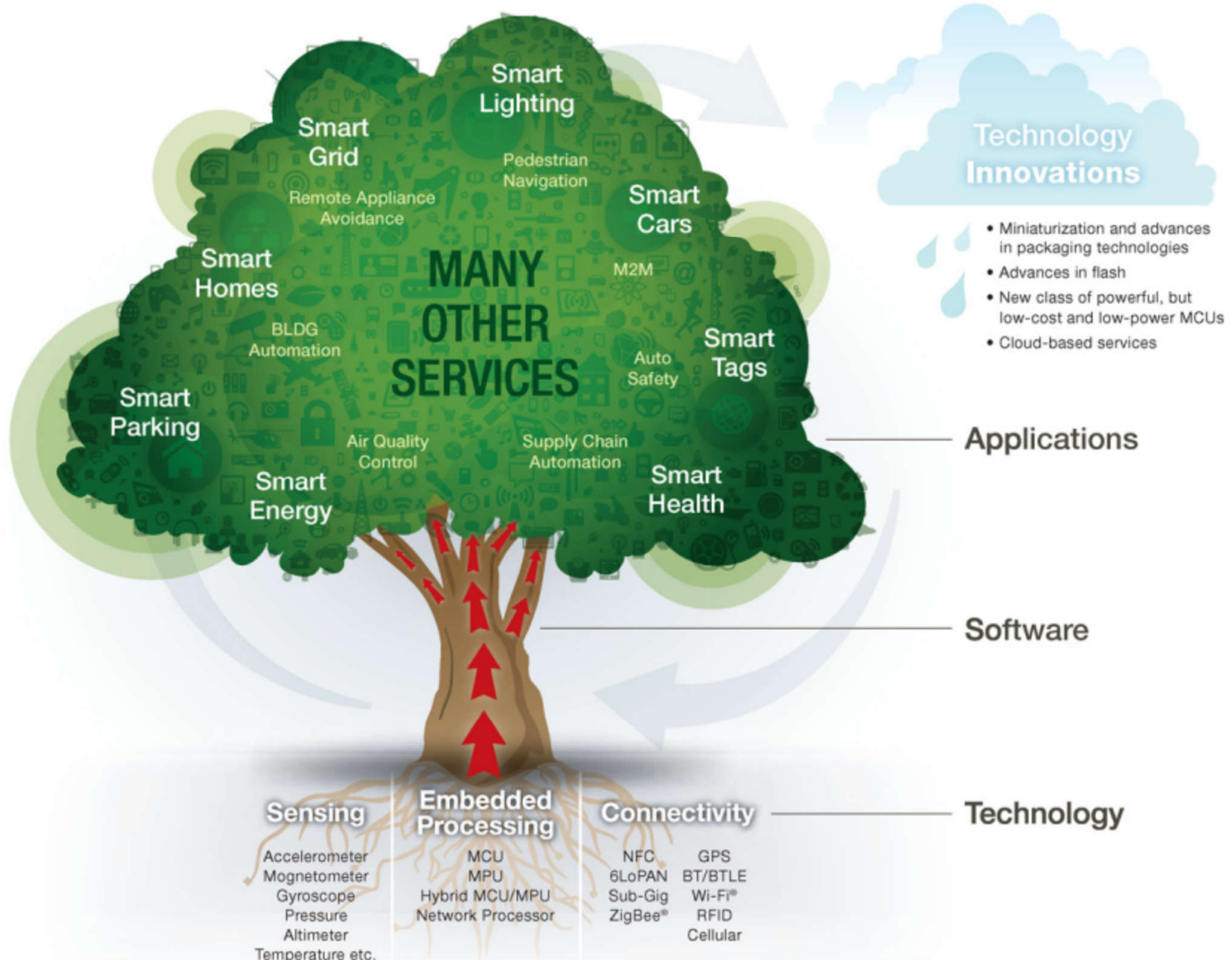
IoT-based smart city

- Smart city IoT examples:
  - 1. <u>IoT public transport</u> – a network of IoT sensors to monitor traffic & improve public transport
  - 2. <u>Smart waste management</u> – improve waste collection, cleansing, detoxification & disposal
  - 3. <u>Smart street lights</u> – manage & control remotely to optimize power consumption
  - 4. <u>Air quality monitoring</u> – can alert air pollutants
  - 5. <u>EV charging stations with IoT connectivity</u> – ensure they are being used effectively

Generalized smart city layered architecture
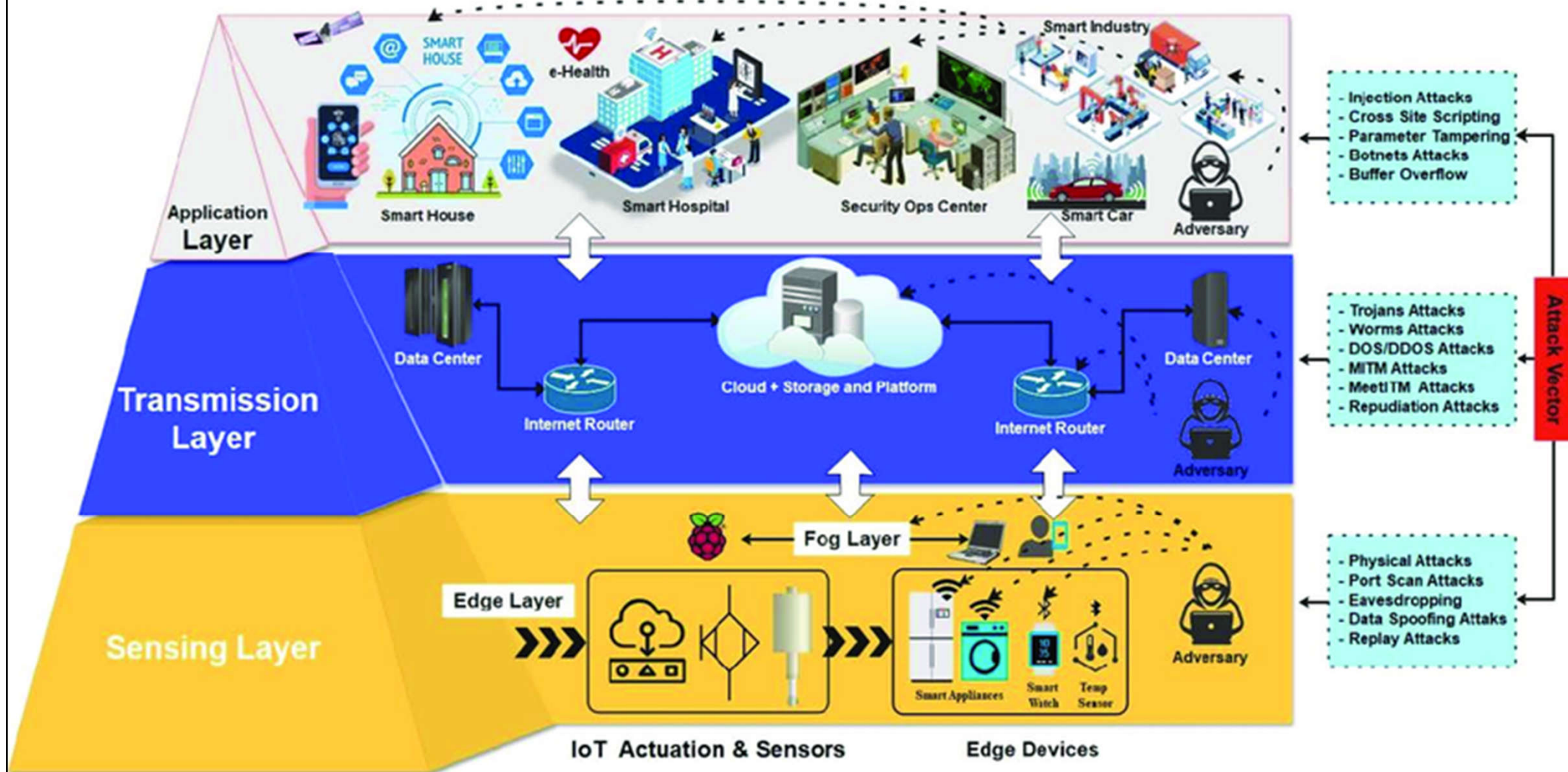
Internet of Things (IoT) layered architecture to support smart cities

Smart Cities	Smart Transport	Smart Buildings	Smart Energy	Smart Industry	Smart Health	Smart Living

Management Capabilities

Generic Management Capabilities
Specific Management Capabilities

Application layer

IoT Applications

Service and Application support layer

Generic Support

Specific Support

Network layer

Networking Capabilities

Transport Capabilities

Device layer

Devices

Gateways

Security Capabilities

Generic Security Capabilities
Specific Security Capabilities

IoT-based smart city

- Implementing IoT in smart cities requires integrating various components:
  - IoT network infrastructure
  - IoT hardware & IoT-enabled devices
  - IoT data management (database solutions)
  - IoT user-friendly interface (e.g. web & mobile)
  - IoT data analytics (to gain valuable insights)
  - IoT security (protect from cyber threats)
  - IoT integration with existing systems

Smart environments & smart spaces creation

Smart Cities

Smart Transport

Smart Buildings

Smart Energy

Smart Industry

Smart Health

KNOWLEDGE CREATION
Data aggregation
Cloud computing
Event management
Data processing

FUTURE NETWORKS
Software Defined Networks
Network Overlay,
Virtualization
Seamless Service
Self-Management

SENSORS NETWORKS
Networks
Topology
Protocols/Standards
Re-configurability
Security.

SEMICONDUCTORS ELECTRONICS
Technology
Components, Circuits
Processors, μCs, NoC
More Moore
More than Moore

SENSORS ACTUATORS
Micro sensors
Nano sensors
Bio sensors
Lab on chip
Actuators

Smart city big data

- For smart city services to take shape, large amounts of data emerging from many sources must be (i) collected, (ii) integrated & (iii) analyzed to generate insights in order to take informed actions & decisions automatically and/or semi-automatically
  - Data collection: with IoT sensors & devices
  - Data integration: with cloud computing
  - Data analysis: with analytics & AI tools

Data framework of smart cities
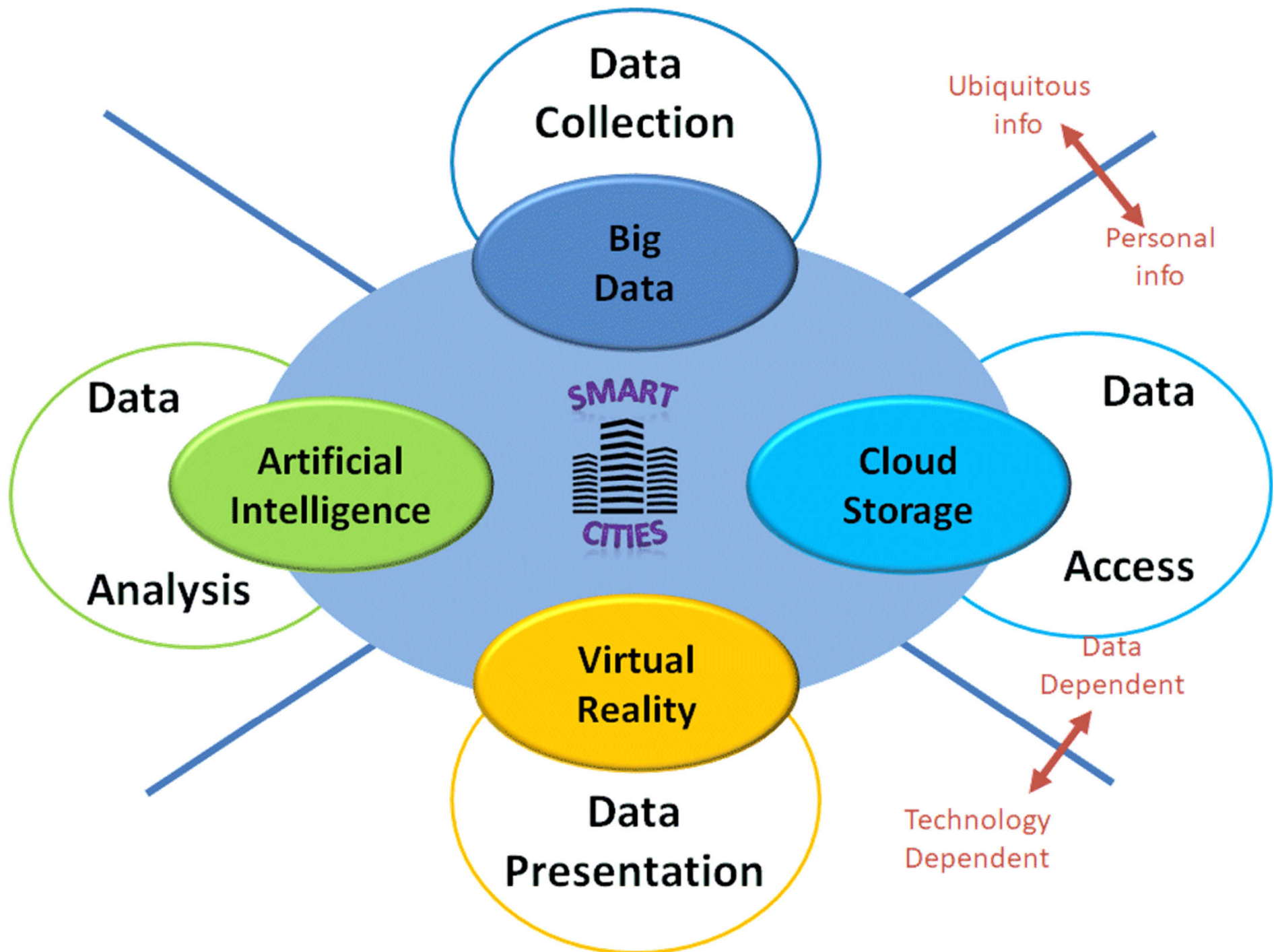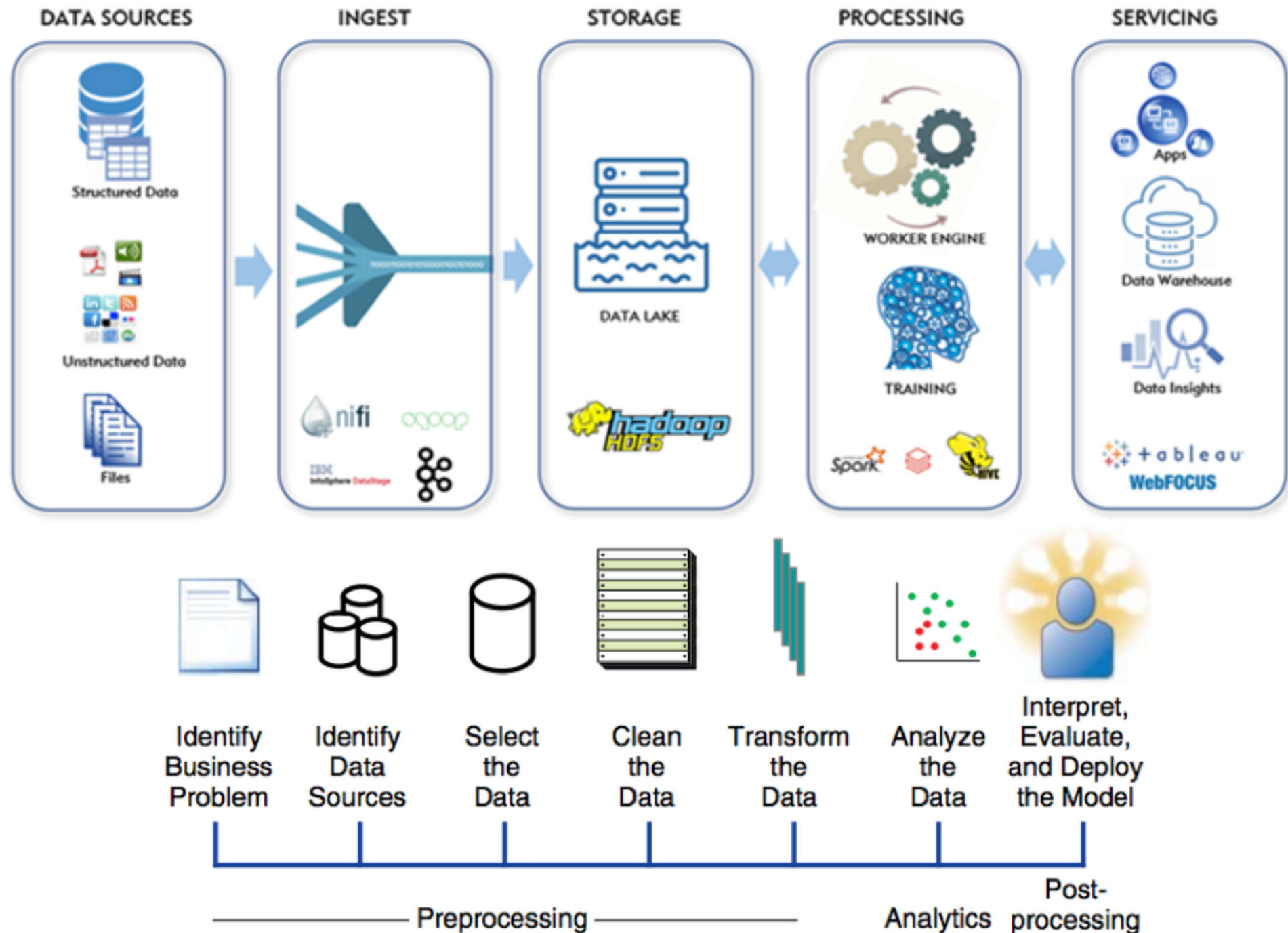
Smart city big data

- A smart city uses sensors & connected devices to collect & analyze data to optimize city operations, manage resources & improve the everyday life of citizens
  - Enhance public transport & manage traffic
  - Improve smart urban lighting & reduce crime
  - Optimize water & power supply
  - Improve law enforcement services, schools, hospitals, and many more

Smart city big data

- Big data analytics for smart cities
  - Gather a huge volume of urban city data
  - Provide descriptive & predictive models as valuable support to inspire & develop data-driven smart city applications & services
  - Use big data analysis & machine learning algorithms to bring improvements in city policies & urban issues e.g. traffic congestion, large-scale resource planning, air pollution, crime, energy consumption, water quality, etc.

Typical steps & software tools of big data analytics

(Source: https://industry40.co.in/smart-city-big-data-analytics/; https://blogs.sas.com/content/sgf/2019/05/14/big-data-in-business-analytics-talking-about-the-analytics-process-model/)

Smart city big data

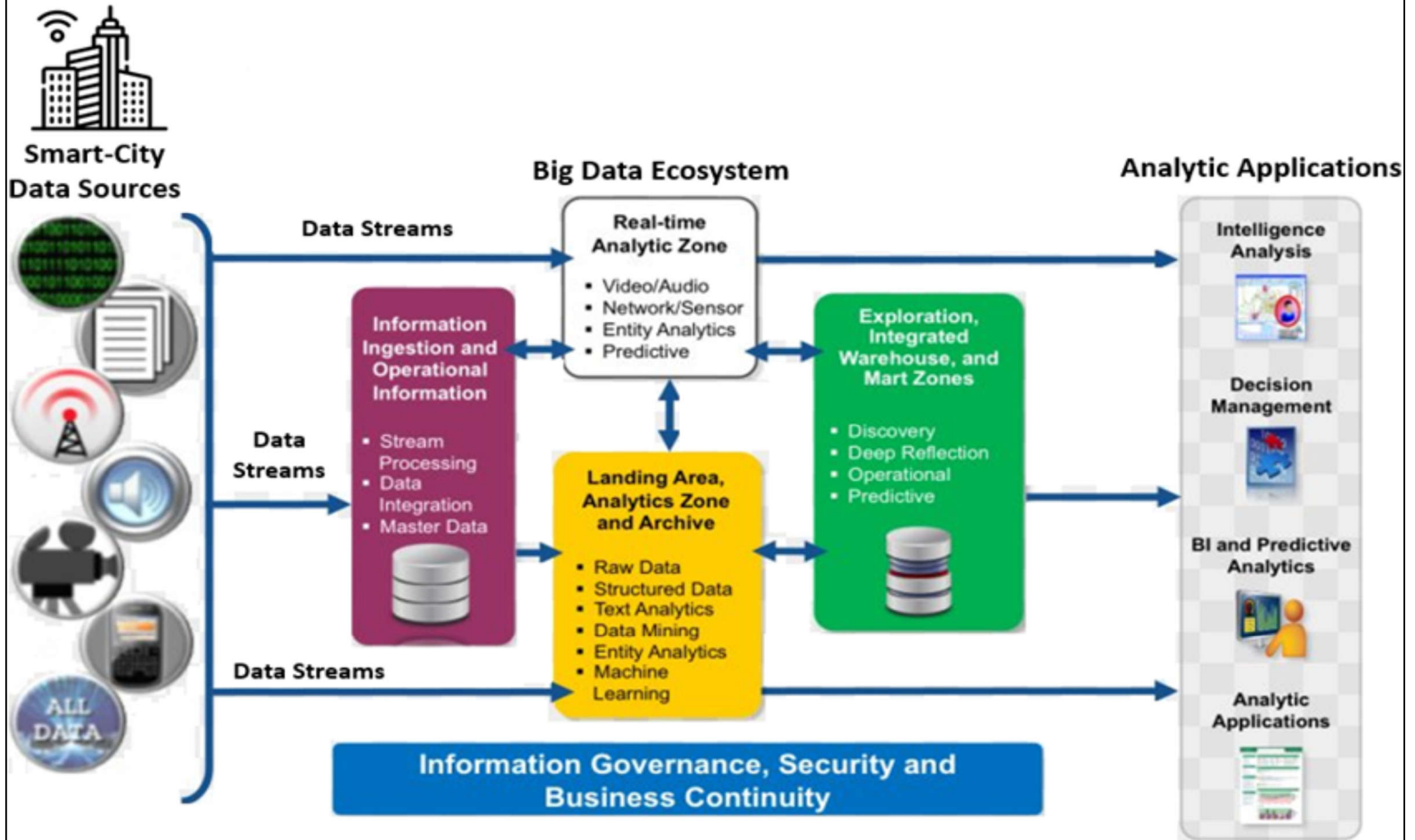- Common big data analytics tools:
  - Data mining (in search of patterns & relationships)
  - Predictive analytics (build forecast models)
  - Machine learning (ML)(to analyze large data sets)
  - Deep learning (a more advanced offshoot of ML)
  - Text mining & statistical analysis software
  - Artificial intelligence (AI)
  - Mainstream business intelligence (BI) software
  - Data visualization tools

Smart city big data

- Key challenges of smart city data analytics:
  - 1. <u>Accessibility of data</u> – Big data should be stored & maintained properly to ensure it can be used by less experienced data scientists & analysts
  - 2. <u>Data quality maintenance</u> – Requires significant time, effort & resources to properly maintain it
  - 3. <u>Data security</u> – The complexity of big data systems presents unique security challenges
  - 4. <u>Choosing the right tools</u> – must pick the tool that aligns with users' needs & infrastructure

High-level logical view of architecture for smart city big data analytics

(Source: https://industry40.co.in/smart-city-big-data-analytics/)

Solution layers of smart city big data analytics

Multi-Channel Delivery	Desktop	Laptop	Mobile	Tablet	Print	Email	SMS

Interaction Layer
- Interactive Dashboards | Reports | Charts & Graphs | Spreadsheets
- Intelligence Analysis Tools | Advanced Analytics Tools | Guided Analysis

Process Layer
- Process-Based Analytic Applications | Industry-Based Analytic Applications | Custom Analytic Applications
- Business & Strategy Planning

Services Layer
- Presentation Services | Business Activity Monitoring | Business Rules
- Information Services | Event Handling

Information Layer
- Data Virtualization
- Data Processing | Event Detection
- In-Memory Analytics | Historical Data | Analytical Data | Discovery Data | In-DB Analytics | Logical Data Warehouse
- Data Ingestion
- System-Generated Data | External Data | COTS Data | Reference Data | Content | Operational Data

Shared Infrastructure
- Database Infrastructure | Big Data Infrastructure | Analytics Infrastructure

(Side bar, vertical): Governance | Security | Monitoring | Management | Modeling

Smart city big data

- Type of data captured will vary widely from images, videos, electricity & water consumption, social media, text, etc.
  - Collection of data using sensors, CCTV cameras, smart energy meters as well as social media engines that capture real-time human activity
- A digitalized eco-system of Big Data & smart environments, augmented by analytics has the potential to drive optimized & informed decision making

Smart city big data

- Core data security objectives of smart cities:
  - 1. <u>Availability</u> – Data needs to be available in real time with reliable access

  - 2. <u>Integrity</u> – The data must be accurate & reliable, preventing manipulation from outside

  - 3. <u>Confidentiality</u> – Sensitive data needs to be kept confidential & safe from unauthorised access

  - 4. <u>Accountability</u> – System users need to be accountable for their actions & interaction with sensitive data systems

Further reading

- What is a Smart City? - Definition and Examples
  https://www.twi-global.com/technical-knowledge/faqs/what-is-a-smart-city

- Smart City – Big Data Analytics
  https://industry40.co.in/smart-city-big-data-analytics/

- SMARTHON Smart City IoT Starter Kit for micro:bit
  https://en.smarthon.cc/micro-bit-smart-city-kit

  - Overview of Smart City IoT Starter Kit for micro:bit by Smarthon (2:00) https://youtu.be/6iYZ4XrWBt4

- Hong Kong Smart City Blueprint 香港智慧城市藍圖
  https://www.smartcity.gov.hk/