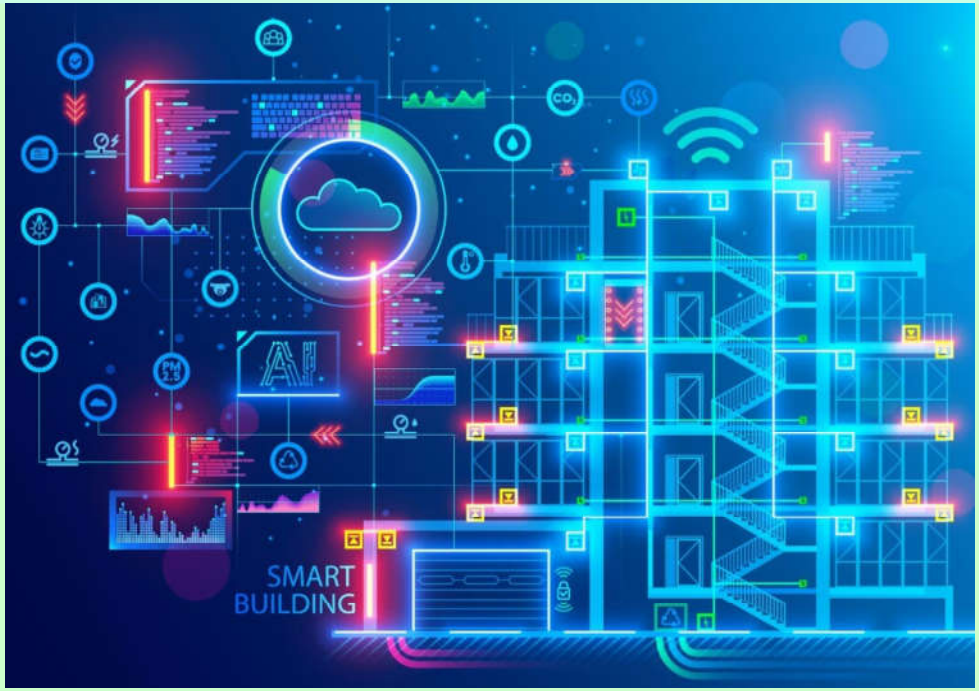
IDAT7219 Smart Building Technology

http://ibse.hk/IDAT7219/



Smart Cities

智能大廈科技

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Feb 2024

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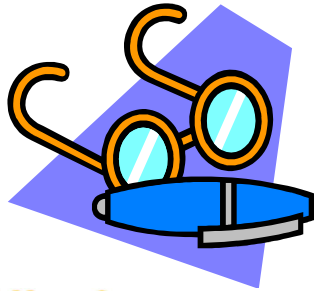
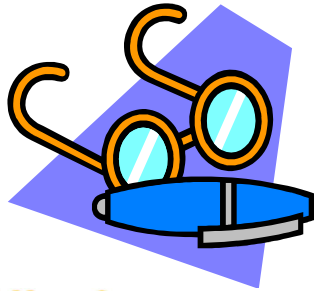
- Basic concepts
- Smart city components
- Smart city ecosystem
- IoT-based smart city
- Smart city big data

Basic concepts



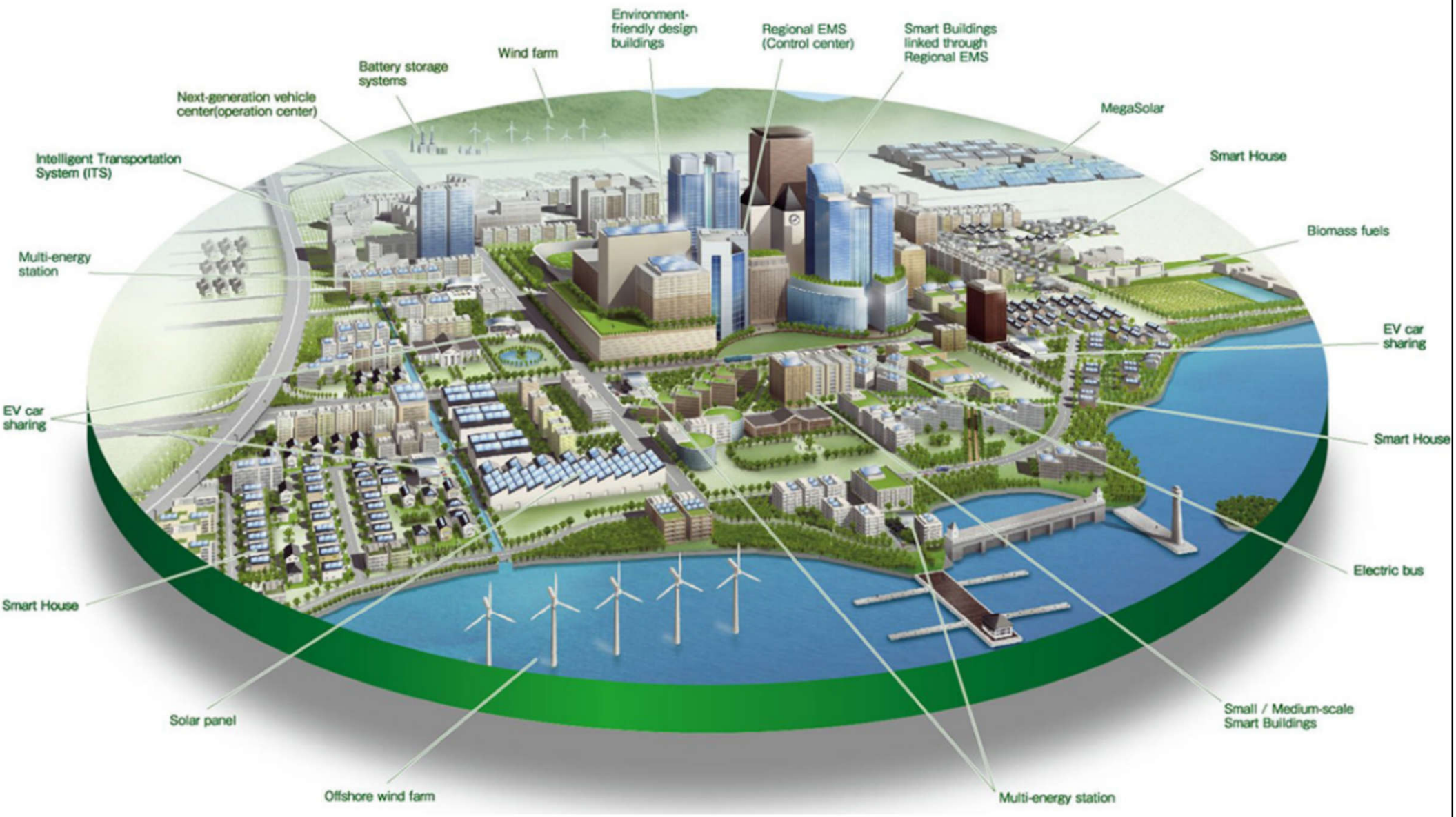
- Cities with heavy populations escalate burden on transportation, energy, water, buildings, security & many other things, resulting in poor livability, workability & sustainability
- Smart City can be defined as “A city that monitors & integrates conditions of all of its critical infrastructures including roads, bridges, tunnels, rails, subways, airports, sea-ports, communications, water & power

Basic concepts



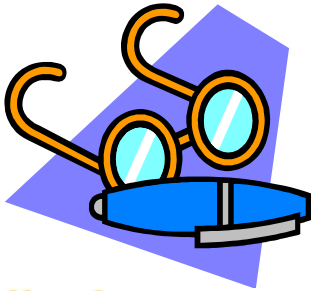
- A smart city uses information & communications technology (ICT) to enhance its livability, workability & sustainability. [Smart Cities Council]
- A smart city is one that makes optimal use of all the interconnected information available today to better understand & control its operations & optimise 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)

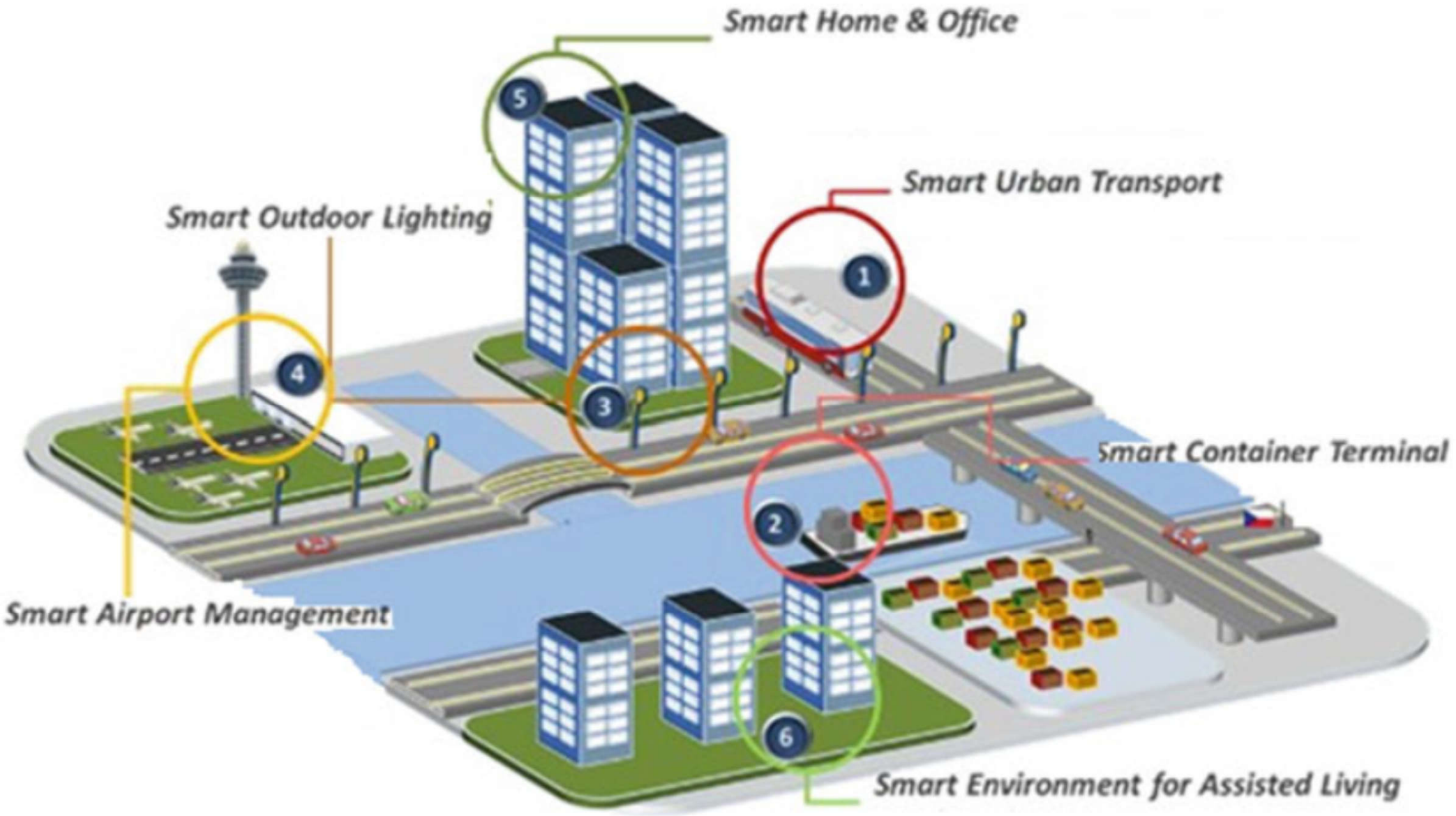
Basic concepts



- 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

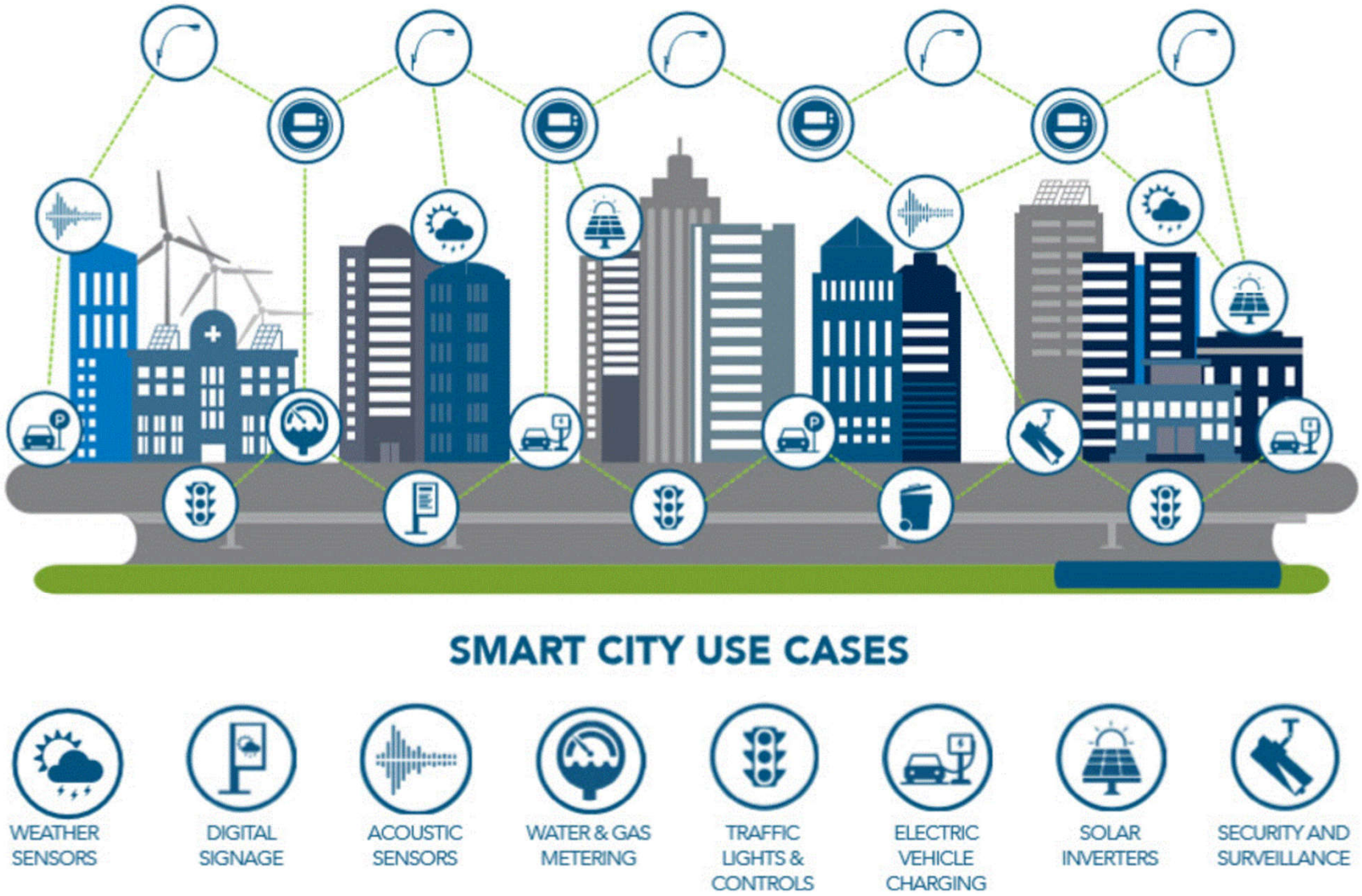
智慧城市

Examples of smart city requirements



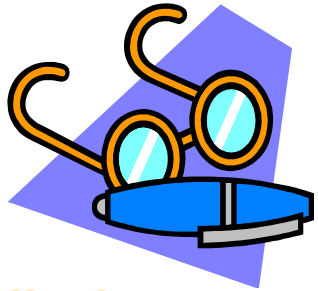
(Source: Ahmed S., Abbas S. M. & Zia H. (eds.), 2019. *Smart Cities--Opportunities and Challenges*, Select Proceedings of ICSC 2019 International Conference on Smart Cities: Opportunities and Challenges (2019 : India), Springer, Singapore. https://doi.org/10.1007/978-981-15-2545-2)

Examples of smart city use cases



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

Basic concepts



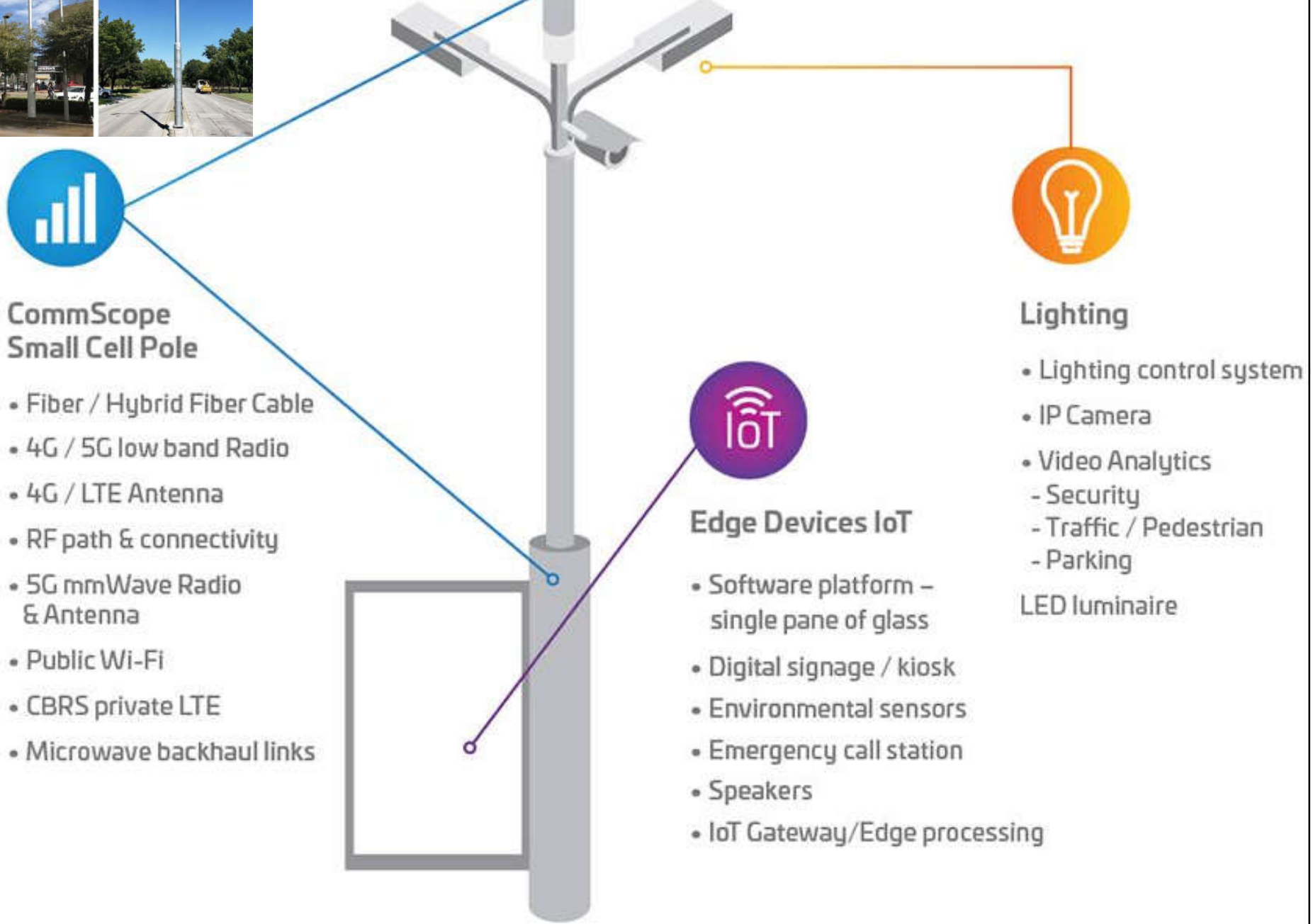
- Smart cities should ensure safe, secure environmentally green & efficient outcomes with all the utility functions e.g. power, water, transportation, etc. are designed, constructed & maintained making use of integrated materials, sensors, electronics & networks which are interfaced with computerized 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 lightning • 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

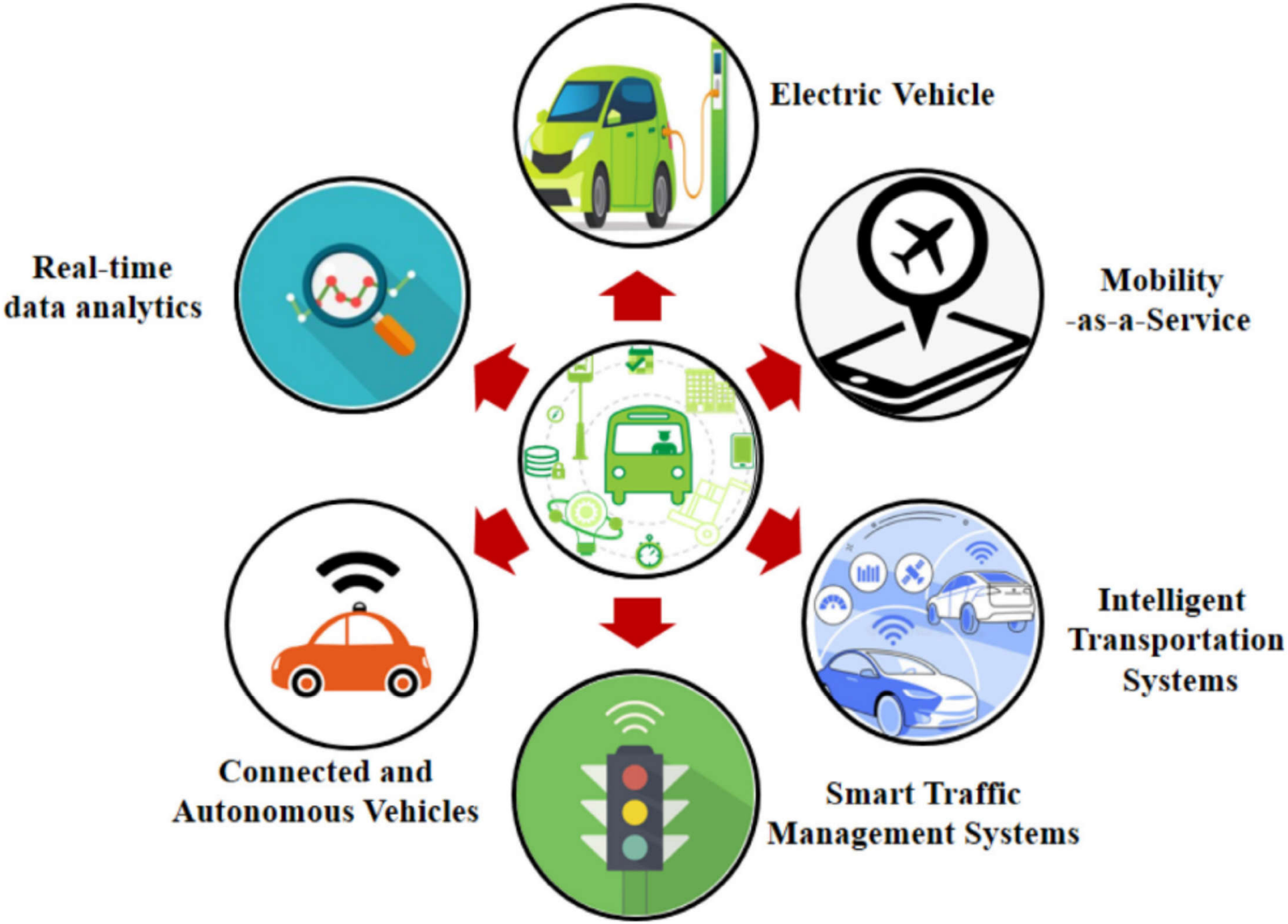
(Source: Vermesan O. & Friess P. (eds.), 2014. *Internet of Things – From Research and Innovation to Market Deployment*, River Publishers, New York. https://doi.org/10.1201/9781003338628)

A smart pole installed in smart cities



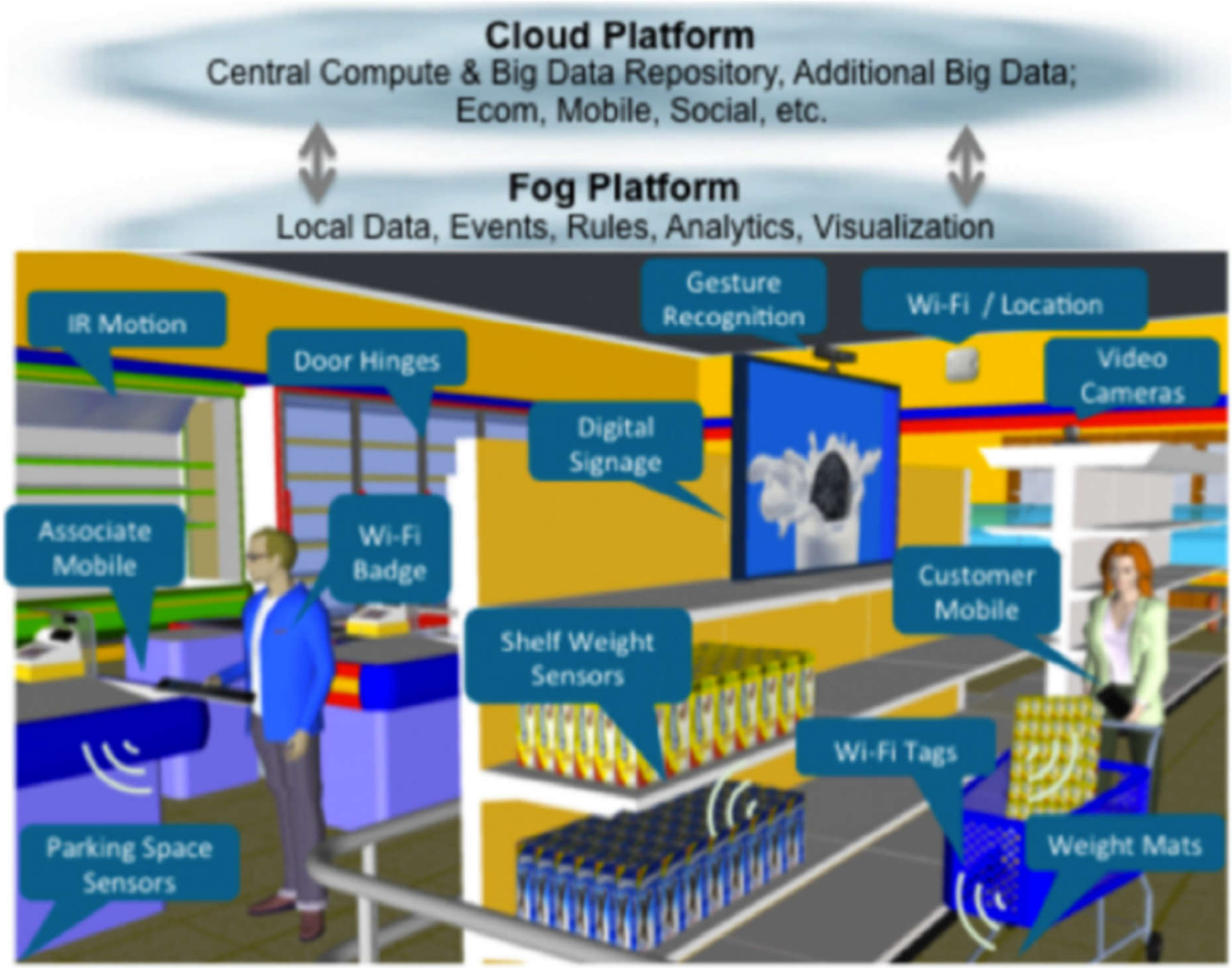
(Source: https://www.commscope.com/insights/the-enterprise-source/smart-spaces-the-fact-file/)

Smart transportation layout



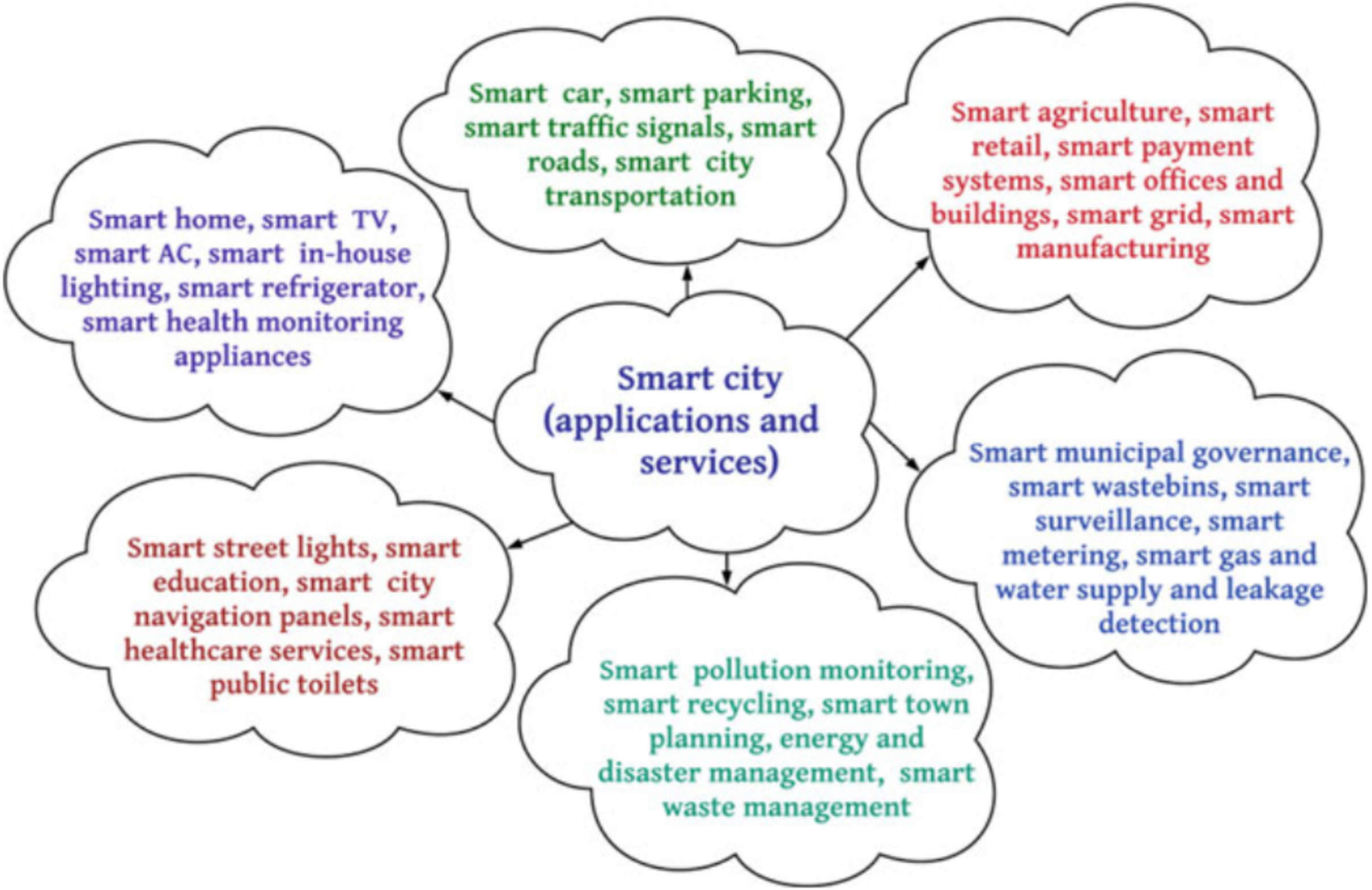
(Source: Pandiyan P., Saravanan S., Usha K., Kannadasan R., Alsharif M. H. & Kim M.-K., 2023. Technological advancements toward smart energy management in smart cities, *Energy Reports*, 10: 648-677. https://doi.org/10.1016/j.egyr.2023.07.021)

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



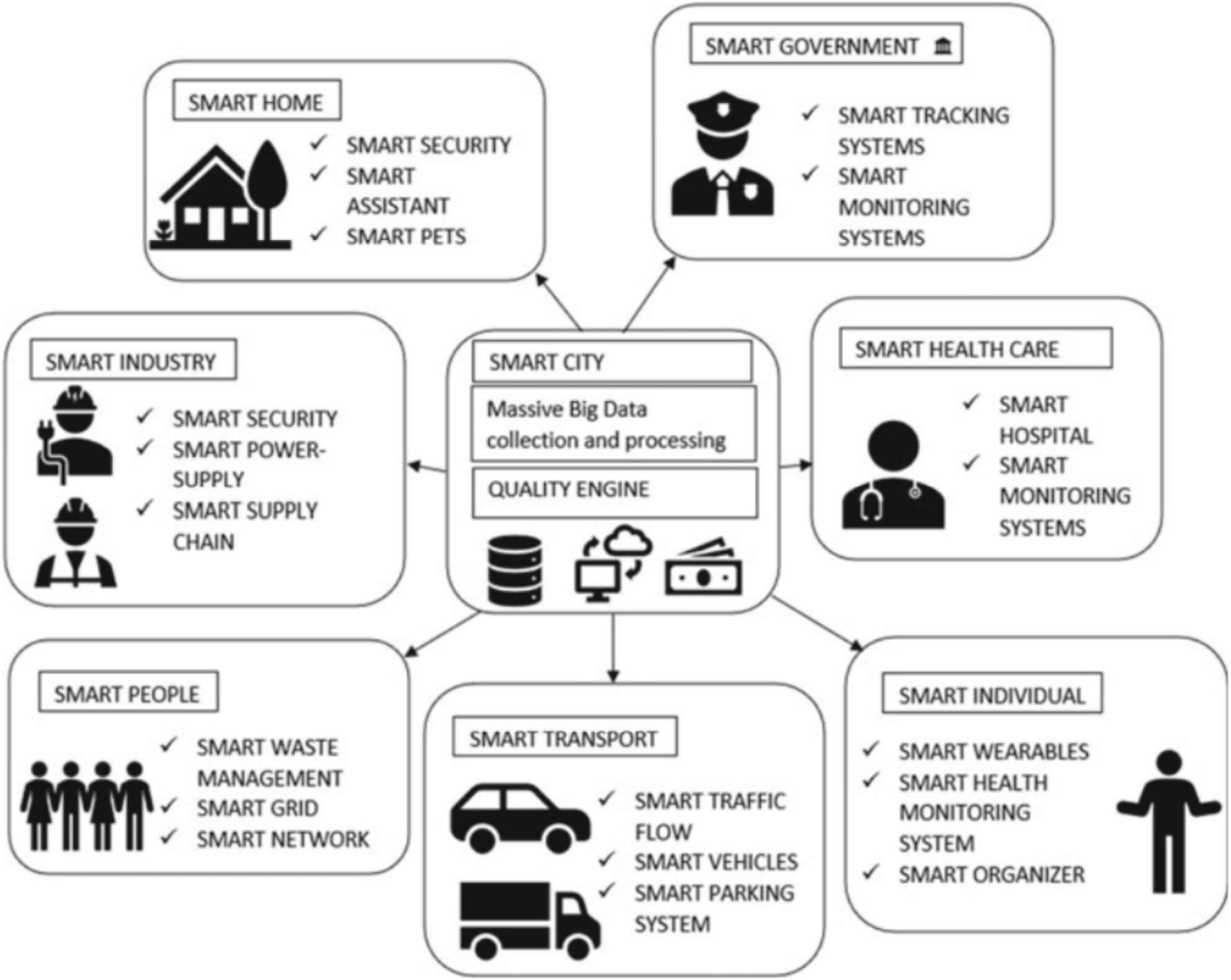
(Source: Vermesan O. & Friess P. (eds.), 2014. *Internet of Things – From Research and Innovation to Market Deployment*, River Publishers, New York. https://doi.org/10.1201/9781003338628)

Applications & services within a smart city



(Source: Chakraborty C., Lin J. C.-W. & Alazab M. (eds.), 2021. *Data-driven Mining, Learning and Analytics for Secured Smart Cities: Trends and Advances*, Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-030-72139-8)

Smart city services & functions

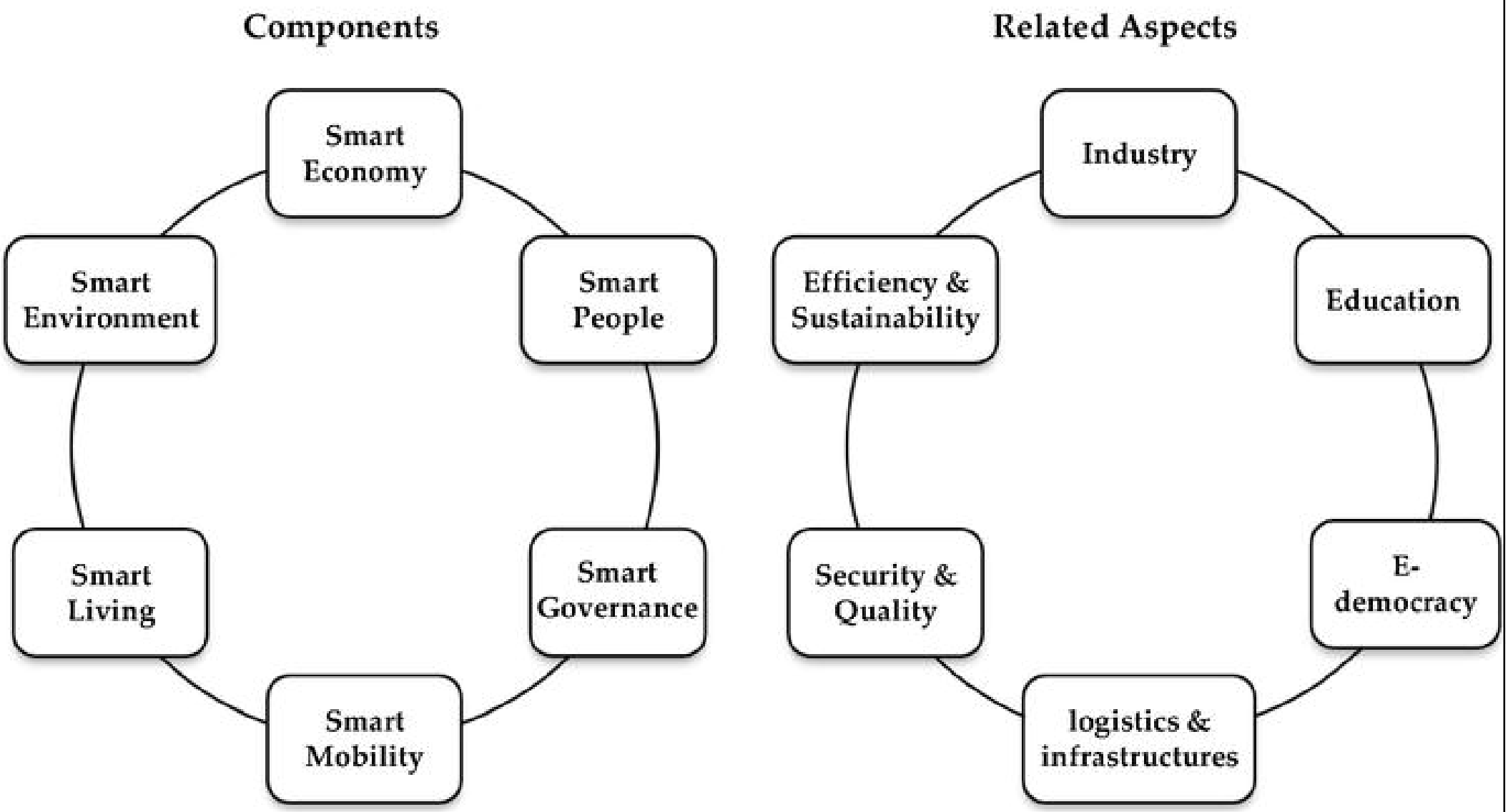


(Source: Srinivasa K. G., Siddesh G. M. & Manisekhar S. R. (eds.), 2022. *Society 5.0: Smart Future Towards Enhancing the Quality of Society*, Springer, Singapore. https://doi.org/10.1007/978-981-19-2161-2)

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



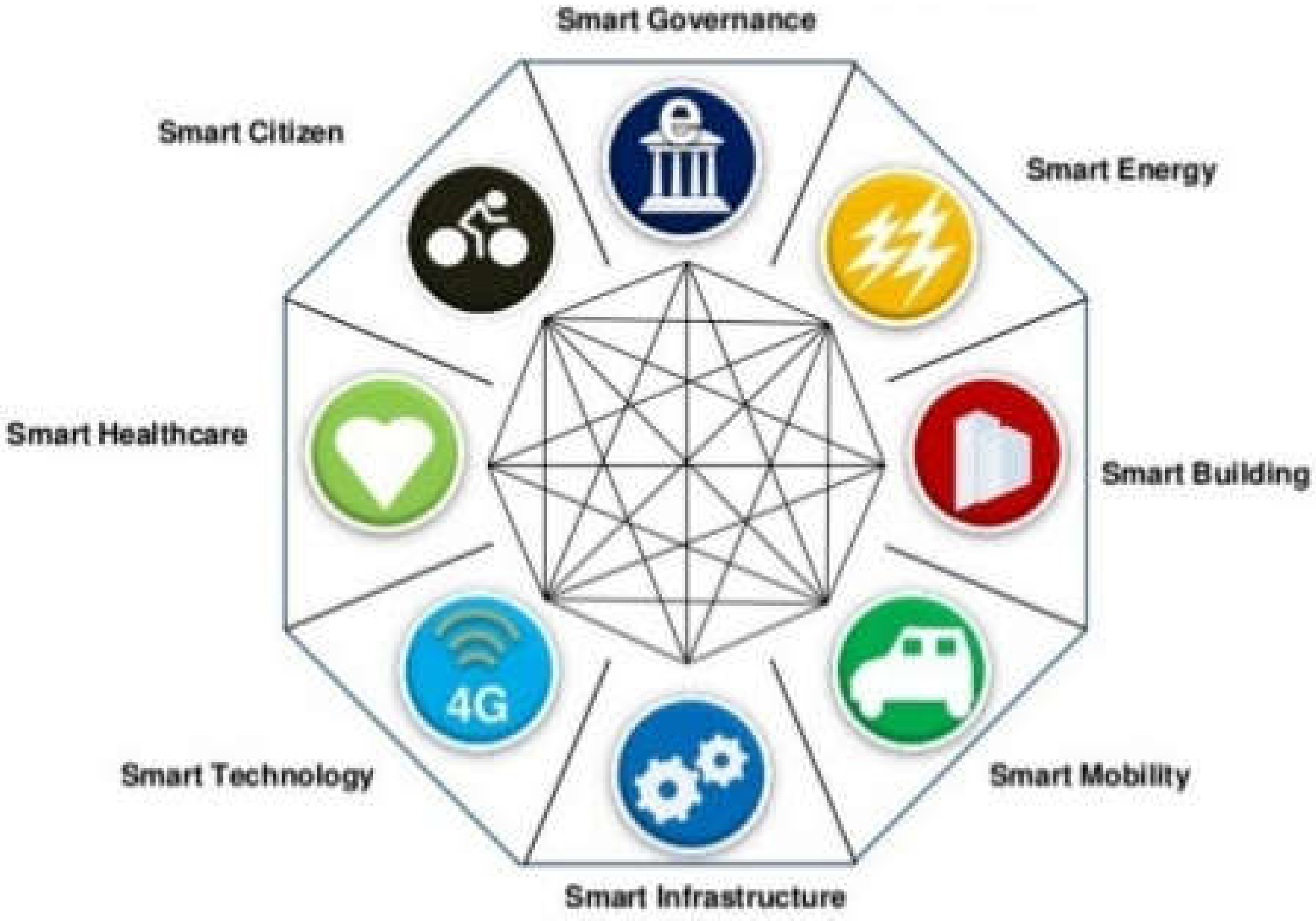
(Source: https://www.intechopen.com/chapters/74934)

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

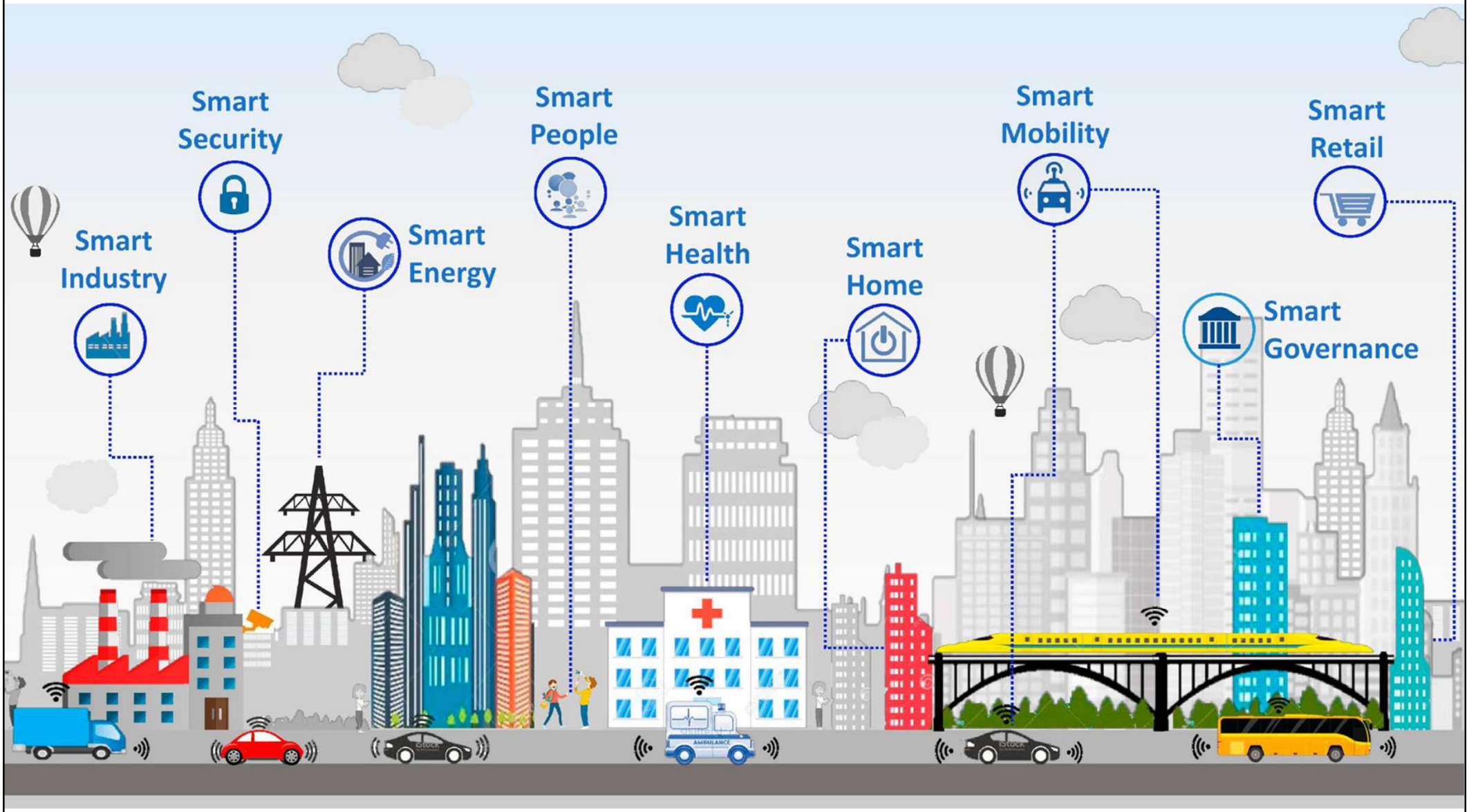
(Source: https://www.intechopen.com/chapters/74934)

Smart diamond to define smart city



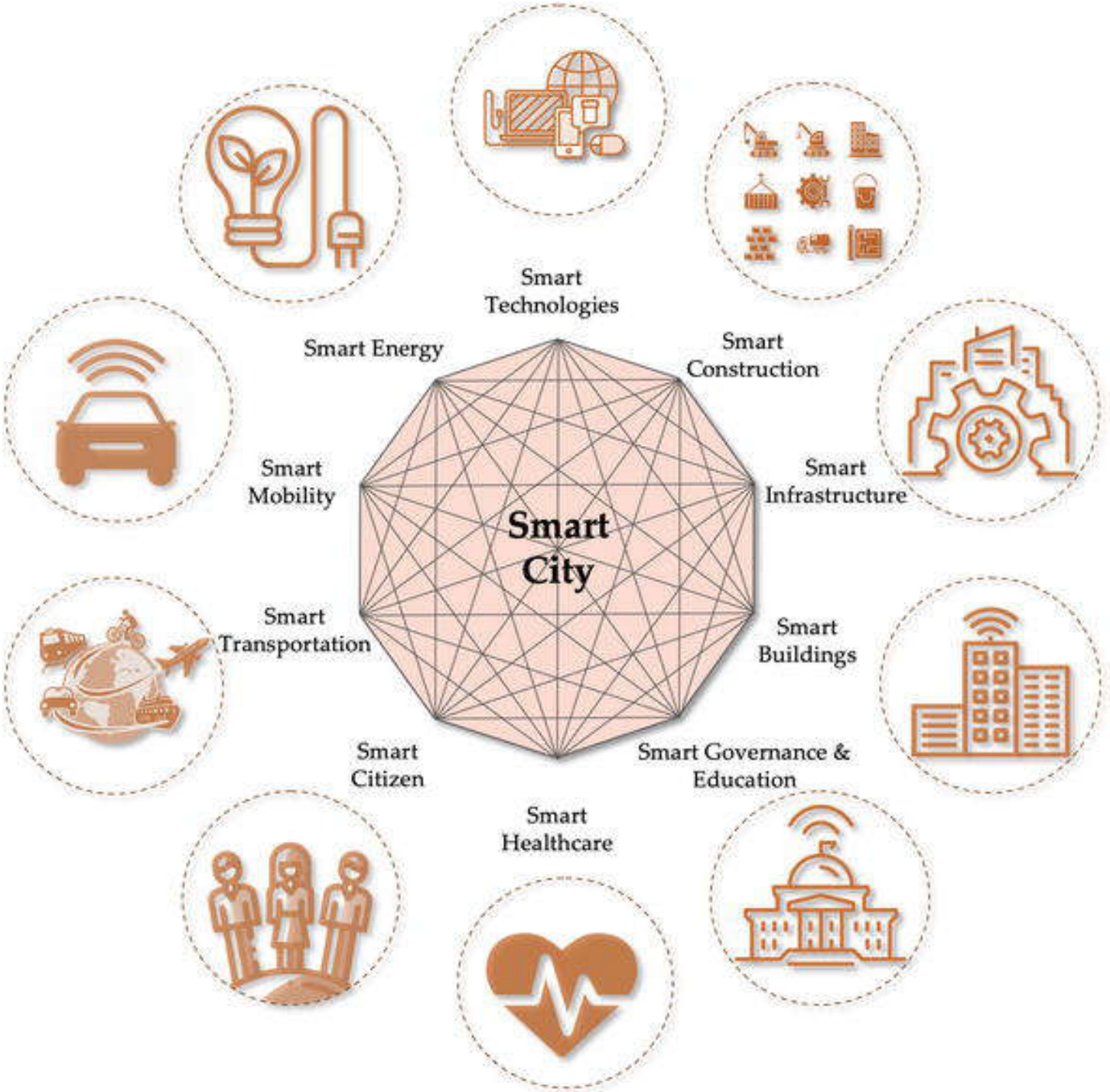
(Source: https://www.quora.com/What-are-the-ten-elements-required-for-making-a-smart-city)

Example of smart city components



(Source: https://www.facebook.com/FutureSmartCitiesConference/)

Smart city components & the connections among them



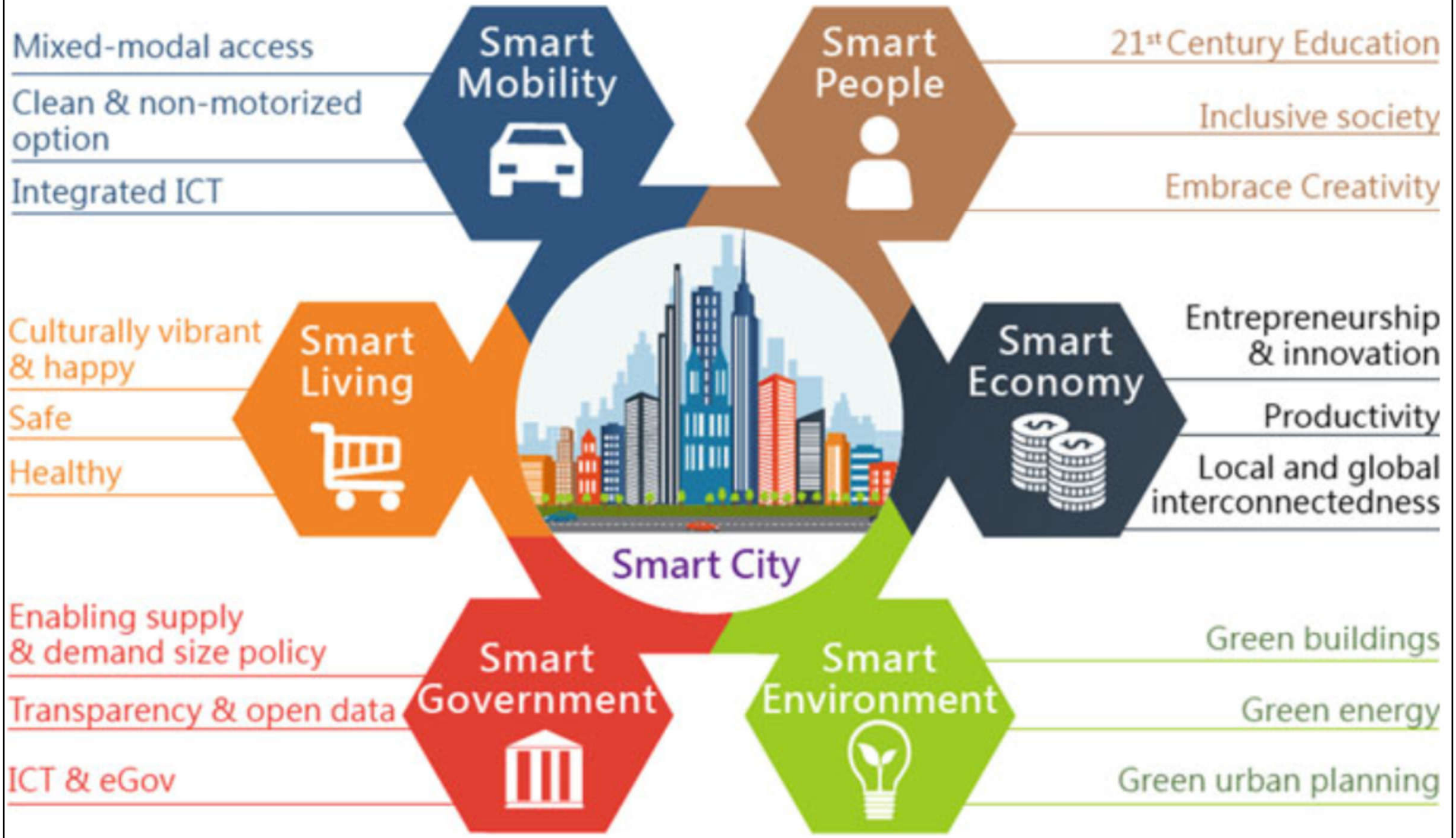
(Source: https://www.intechopen.com/chapters/74934)

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

(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 & requirements of smart city



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Smart solutions & infrastructure elements for smart cities

E-Governance and Citizen Services

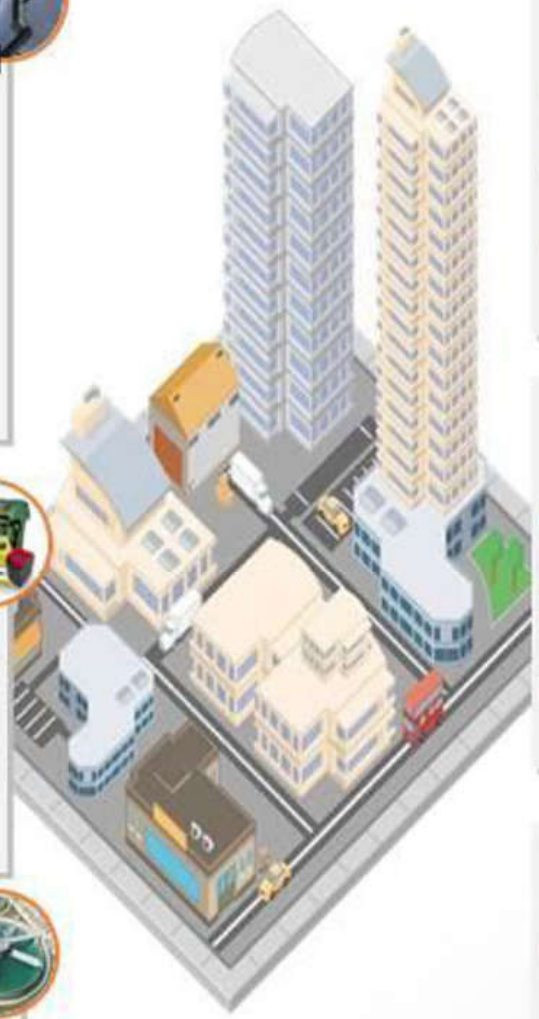
1. Public Information, Grievance Redressal
2. Electronic Service Delivery
3. Citizen Engagement
4. Citizens - City's Eyes and Ears
5. Video Crime Monitoring

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

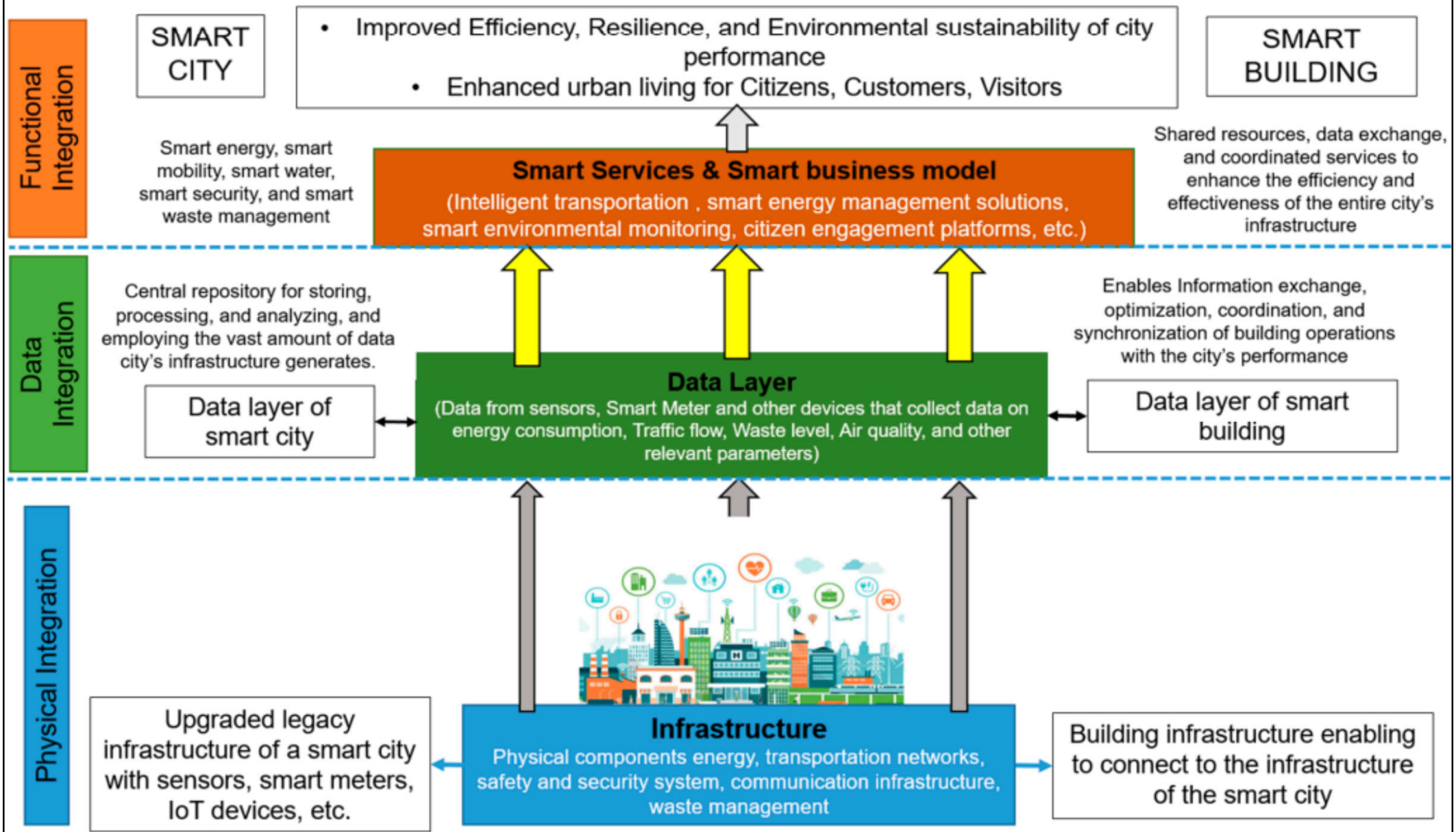
Conceptual illustration of an operational smart city

(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

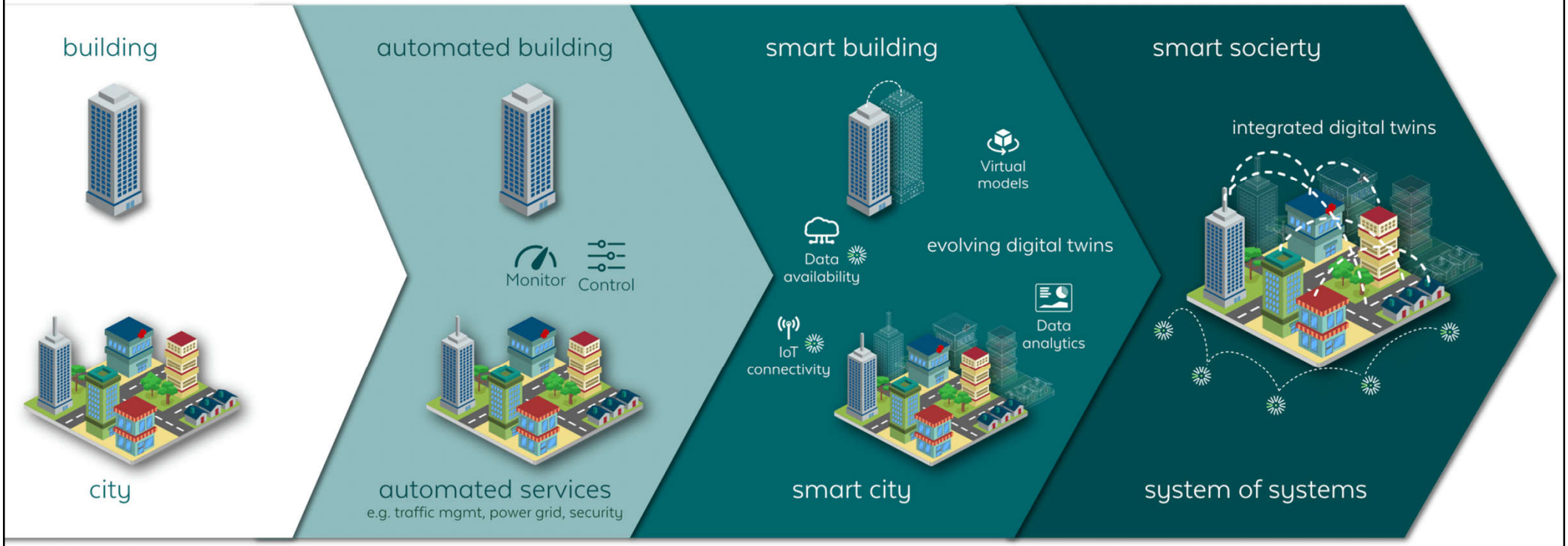


(Source: Apanavičienė R. & Shahrabani M. M. N., 2023. Key factors affecting smart building integration into smart city: technological aspects, *Smart Cities*, 6 (4) 1832-1857. https://doi.org/10.3390/smartcities6040085)

Smart city ecosystem

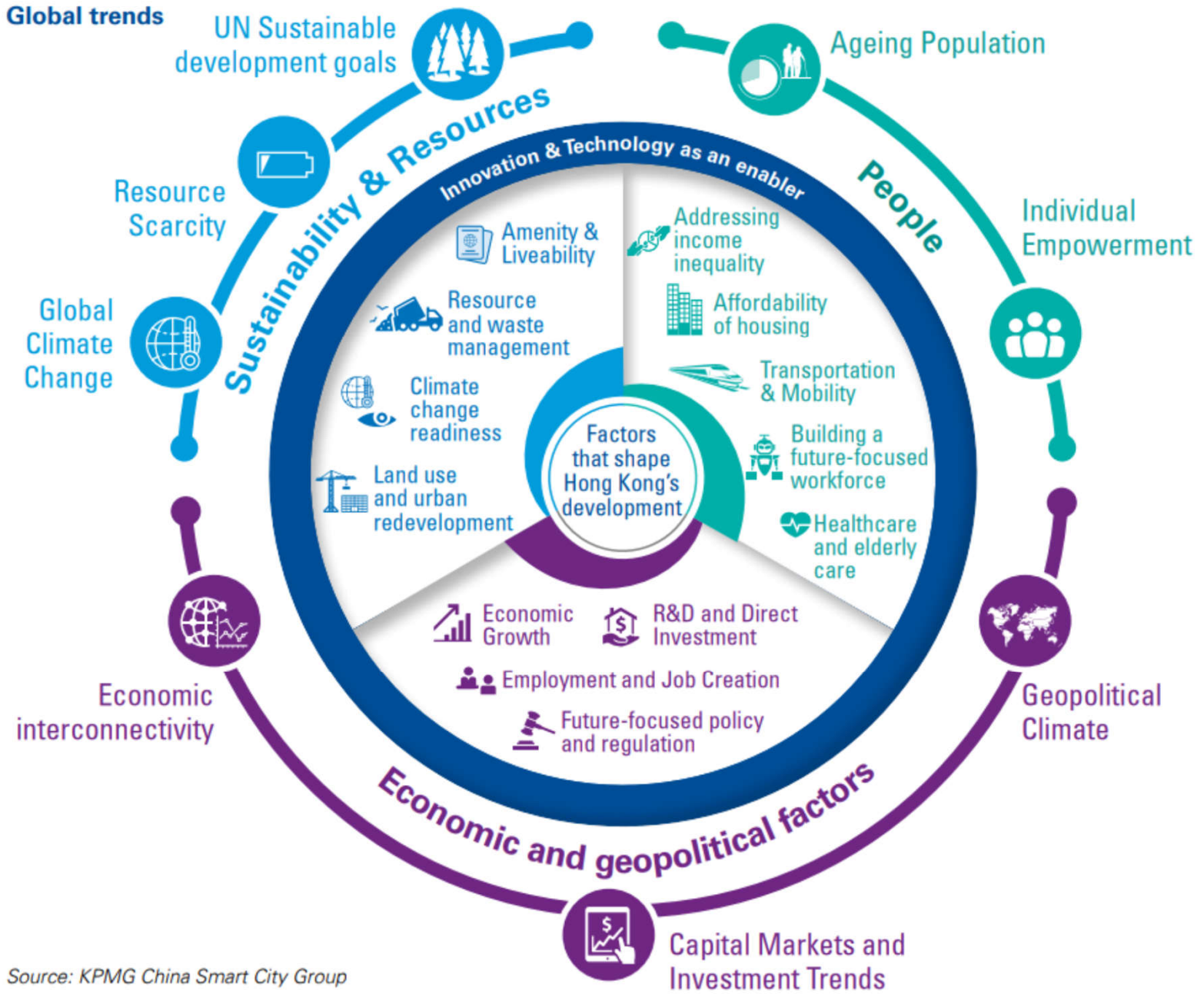
- Smart buildings are connected & can provide a platform for multiple services that help to enhance the development of the smart city
  - For example, the smart grid is the link between the smart building and the smart city
- Smart society is one dimension of the smart city, focusing on humans as city 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



(Source: https://sensative.com/iot-use-cases-by-sensative/digital-twin/)

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



(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)

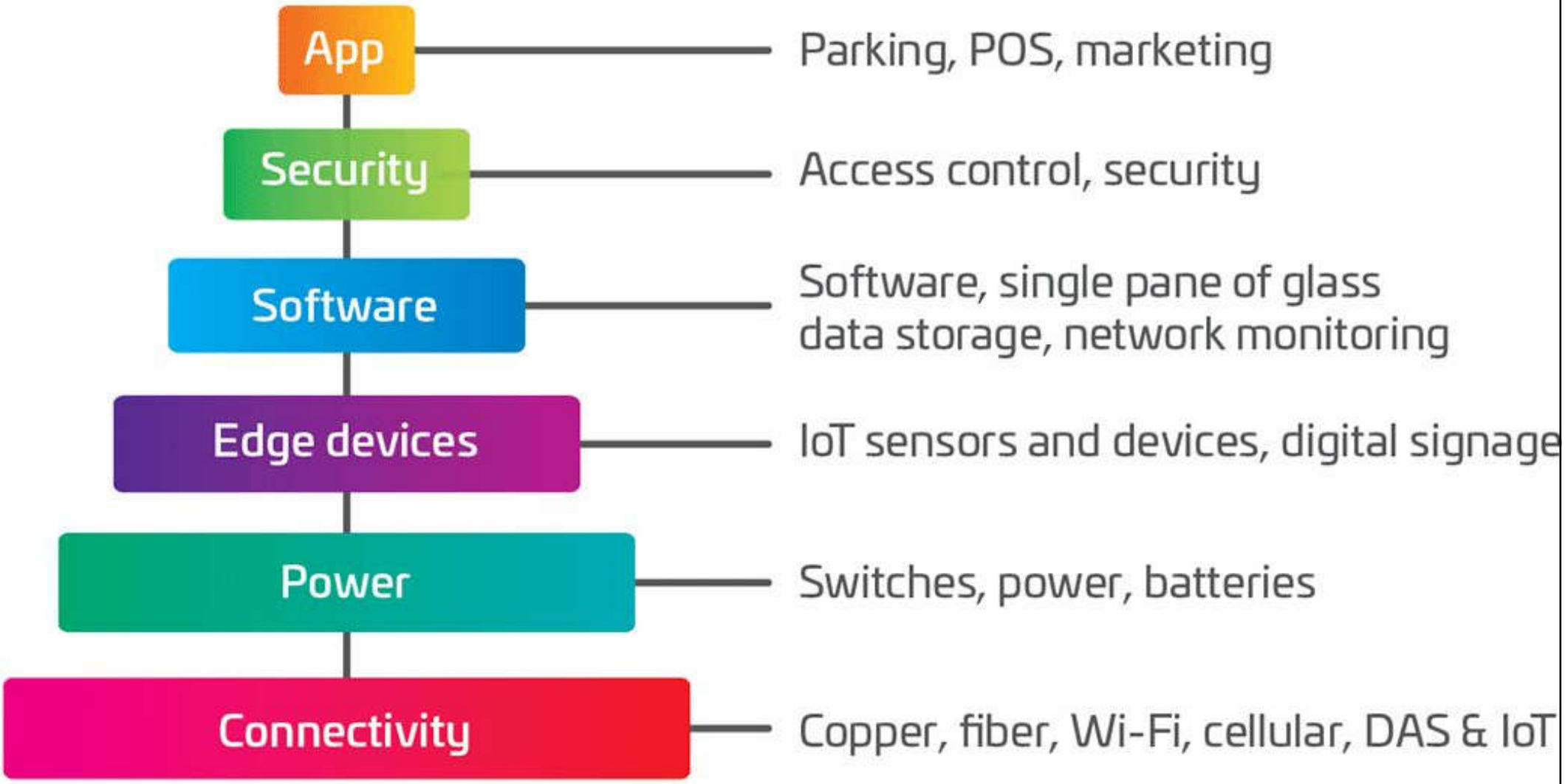
Smart city ecosystem

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

Smart city ecosystem

- How smart cities work?
  - 1. Collection – Smart sensors gather real-time data
  - 2. Analysis – The data is analysed to gain insights into the operation of city services & operations
  - 3. Communication – The results of the data analysis are communicated to decision makers
  - 4. Action – Action is taken to improve operations, manage assets & improve the quality of city life for the residents

Different layers of infrastructure for smart cities

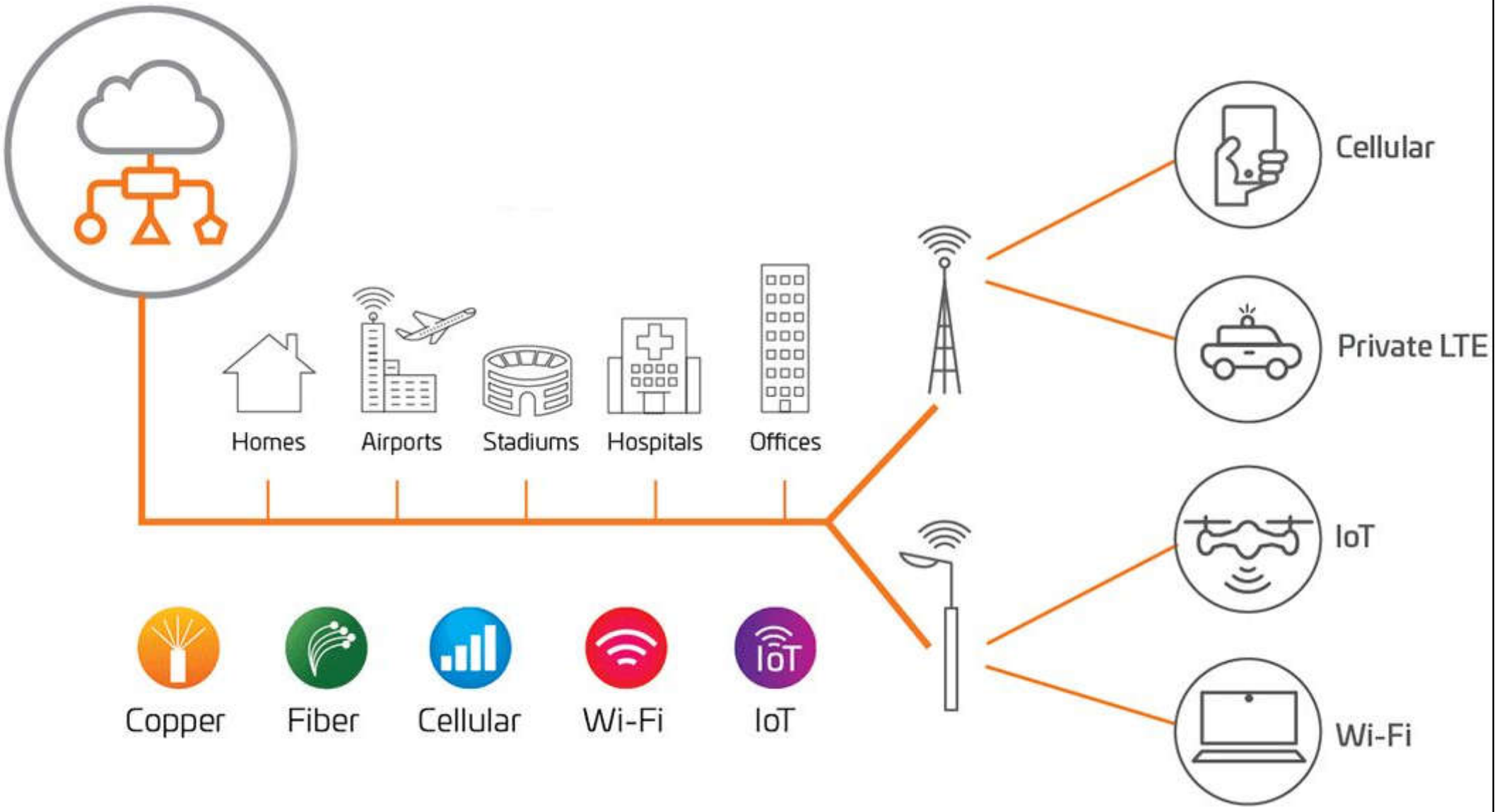


(Source: https://www.commscope.com/insights/the-enterprise-source/smart-spaces-the-fact-file/)

Smart city ecosystem

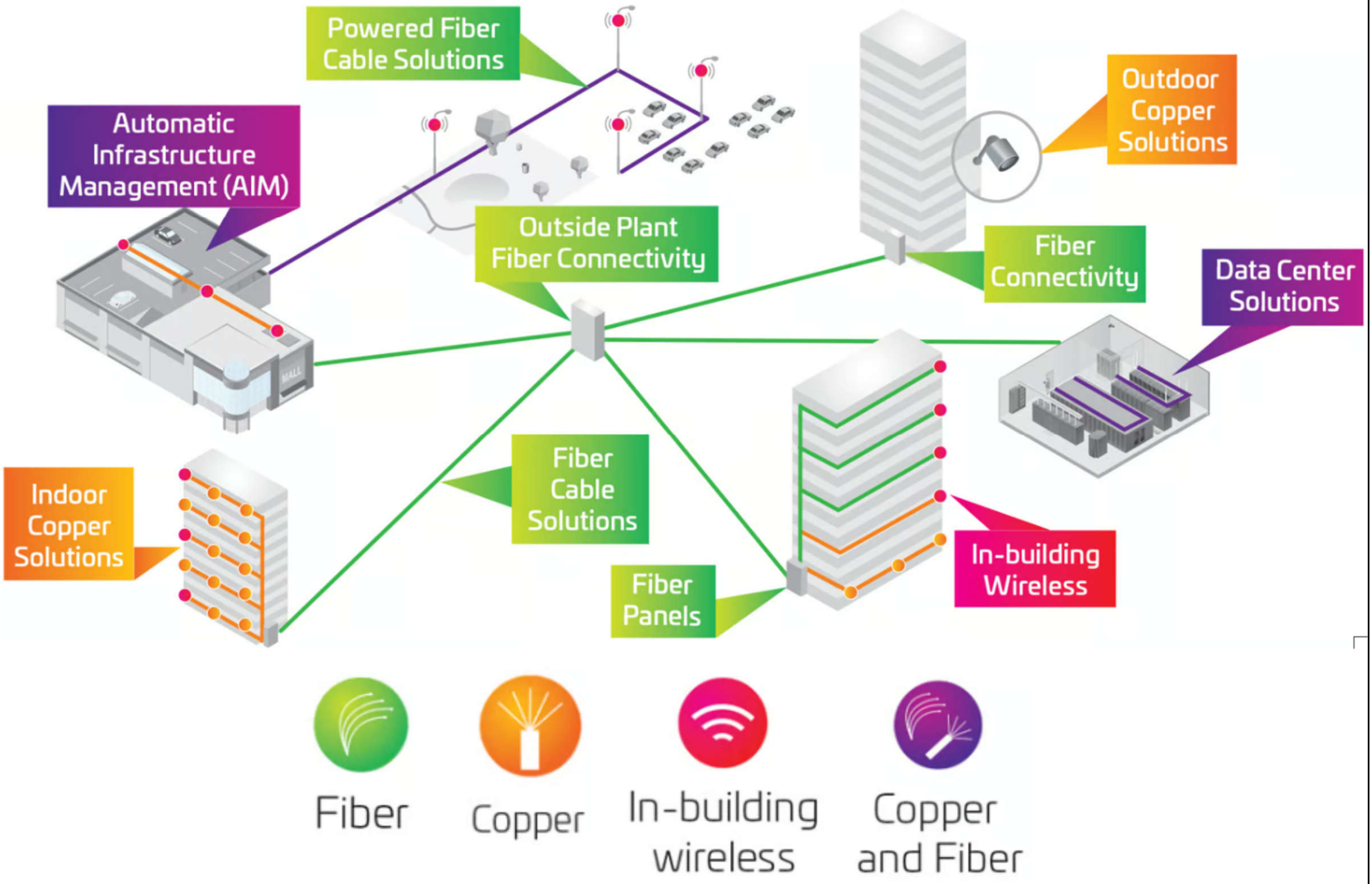
- Technologies used in smart cities:
  - Data acquisition with sensors & IoT
  - Network & communication technology
  - Cloud computing & data centres
  - Edge computing (at the device end)
  - Software-defined networks (SDN)
  - Block chain (retains authentication & security)
  - Big data (analysis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

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



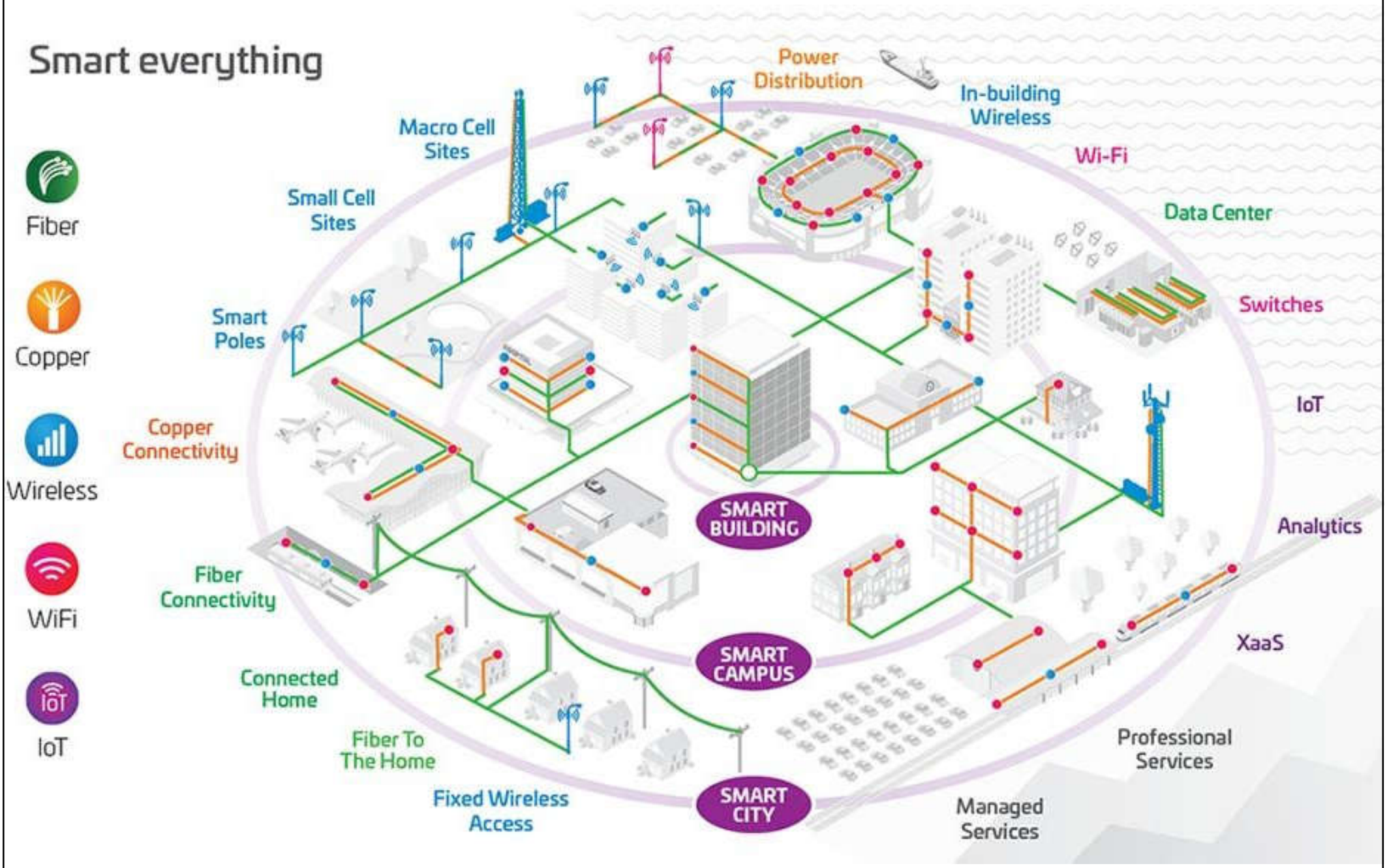
(Source: https://www.commscope.com/insights/the-enterprise-source/smart-spaces-the-fact-file/)

Smart campus network



(Source: https://www.commscope.com/da/connected-campus-interactive-map/)

From smart building to smart campus to smart city

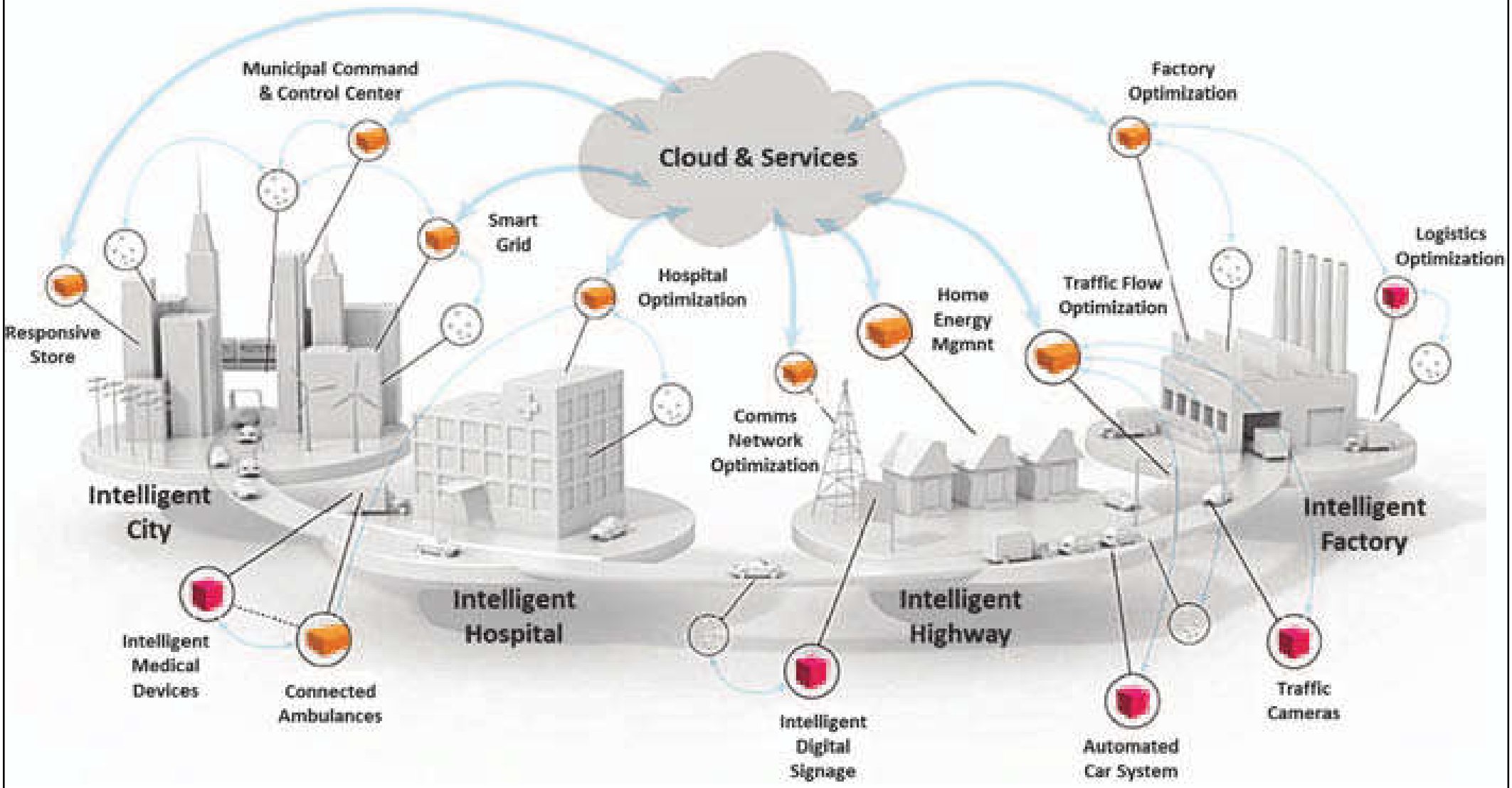


(Source: https://www.commscope.com/insights/the-enterprise-source/smart-spaces-the-fact-file/)

IoT-based smart city

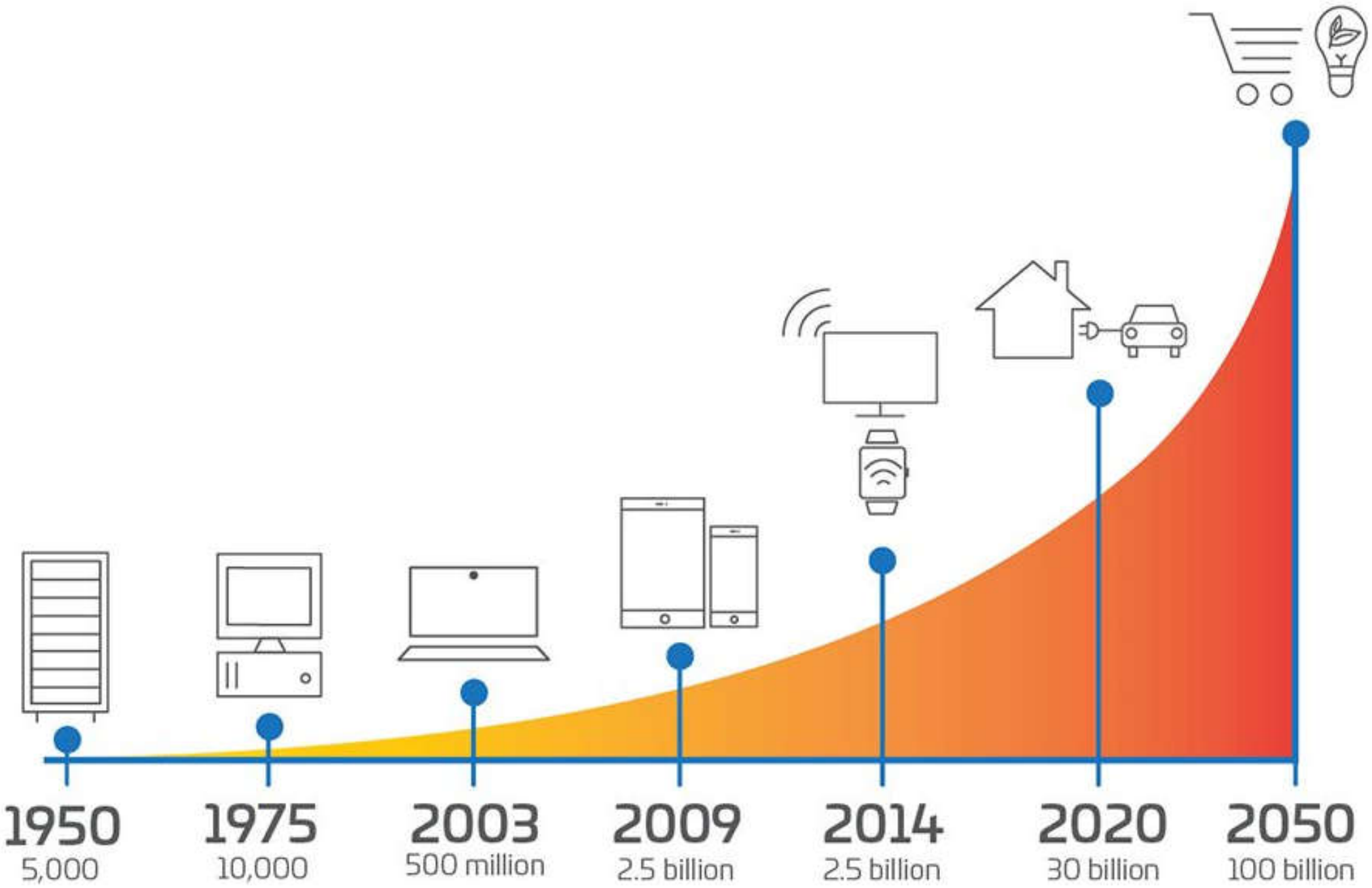
- Internet of City Things (IoCT)
  - Smart cities use IoT devices (e.g. sensors, lights & meters) to collect & analyze data
  - The cities then use this data to improve infrastructure, public utilities & services, etc.
  - Using IoT to create smarter, more connected cities requires a reliable & efficient 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



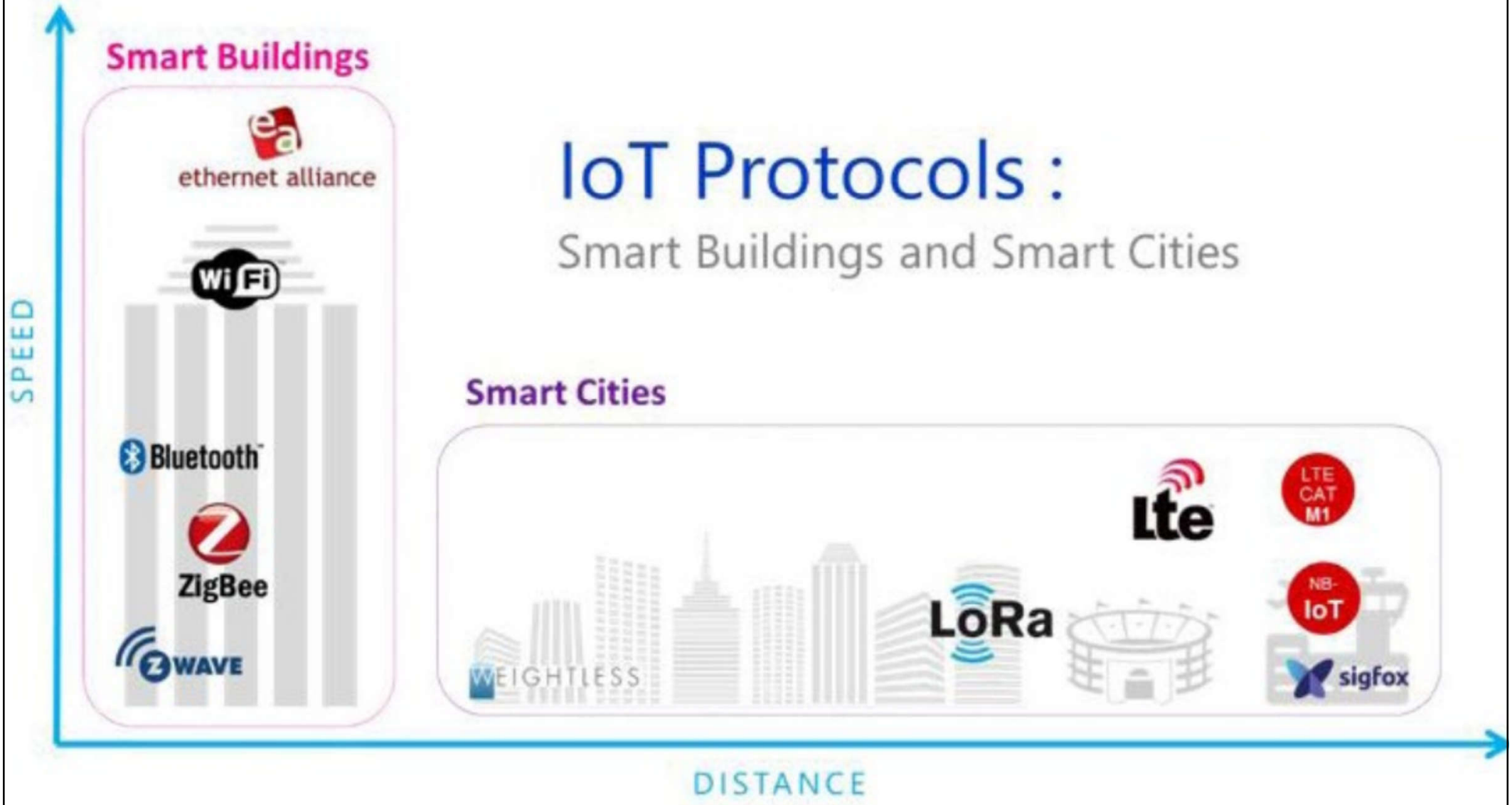
(Source: Vermesan O. & Fries P. (eds.), 2013. *Internet of Things - Converging Technologies for Smart Environments and Integrated Ecosystems*, River Publishers, Aalborg, Denmark.)

Expected adoption growth of IoT devices



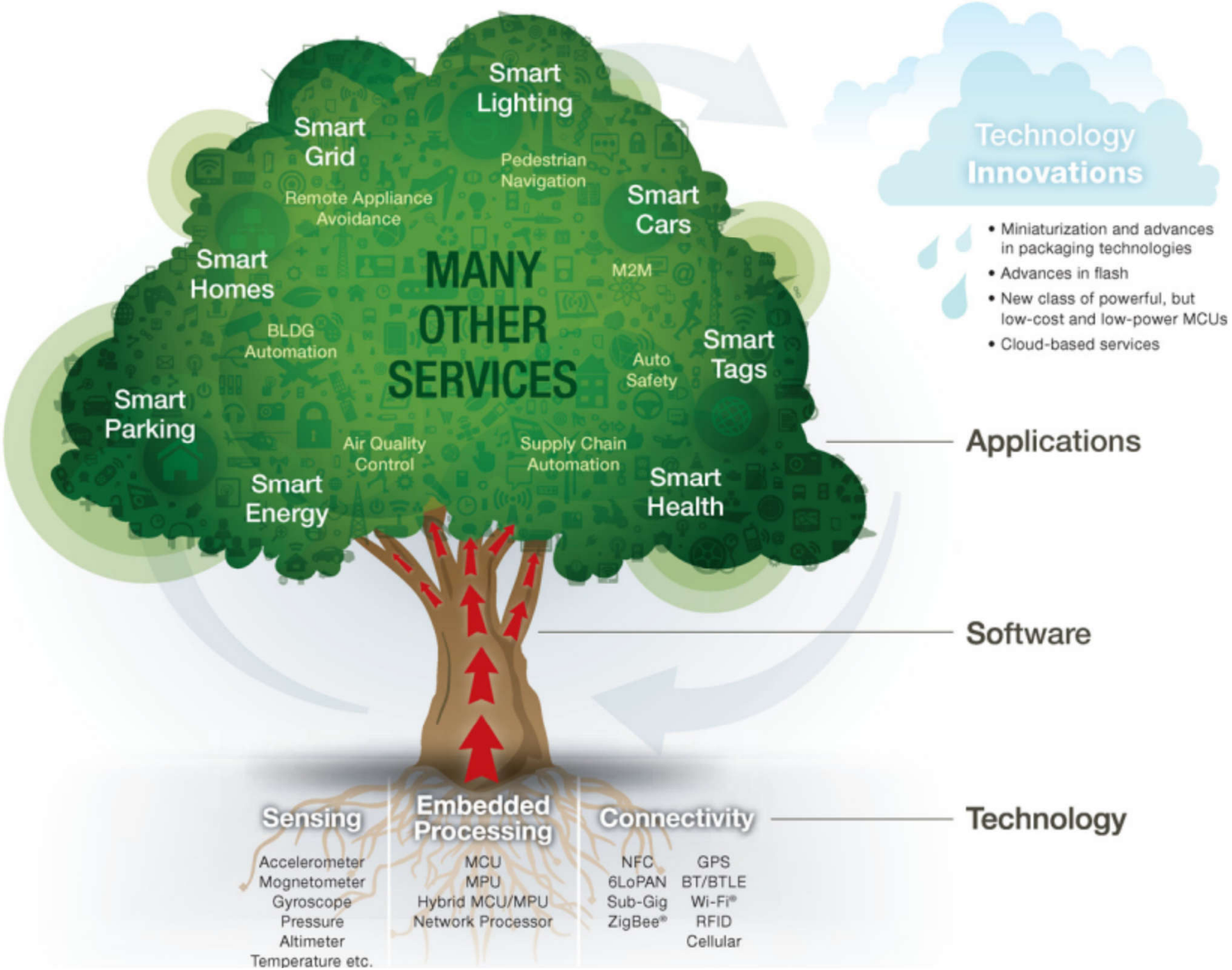
(Source: Capra M., Peloso R., Masera G., Roch M. R. & Martina M., 2019. Edge computing: a survey on the hardware requirements in the Internet of Things world, *Future Internet*, 11 (4) 100. https://doi.org/10.3390/fi11040100)

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



(Source: Smart Building Connectivity https://www.commscope.com/globalassets/digizuite/3296-Smart-Building-eBook-CO-109520-EN.pdf)

The IoT: different services, technologies, meanings for everyone

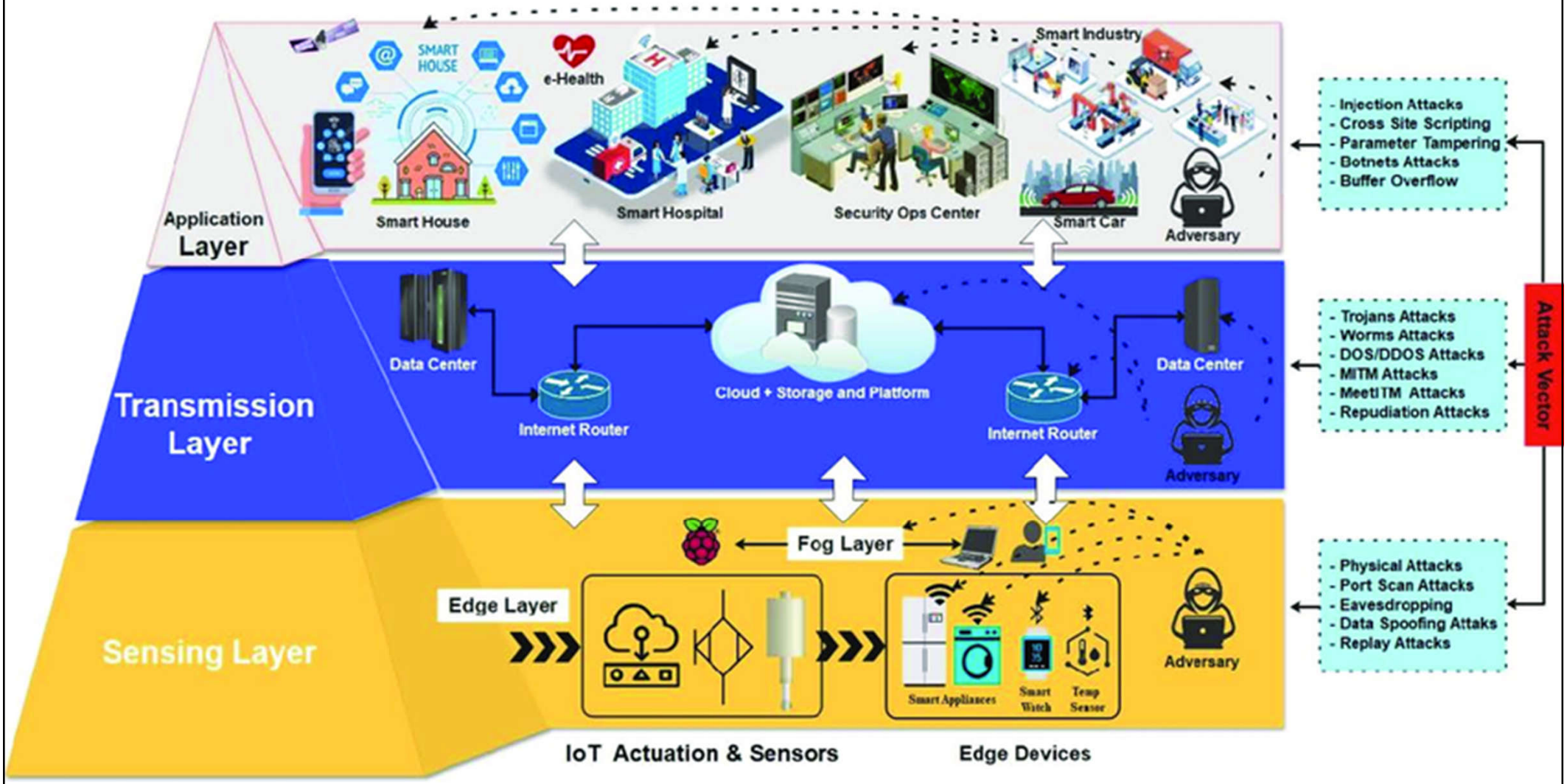


(Source: Vermesan O. & Friess P. (eds.), 2014. *Internet of Things – From Research and Innovation to Market Deployment*, River Publishers, New York. https://doi.org/10.1201/9781003338628)

IoT-based smart city

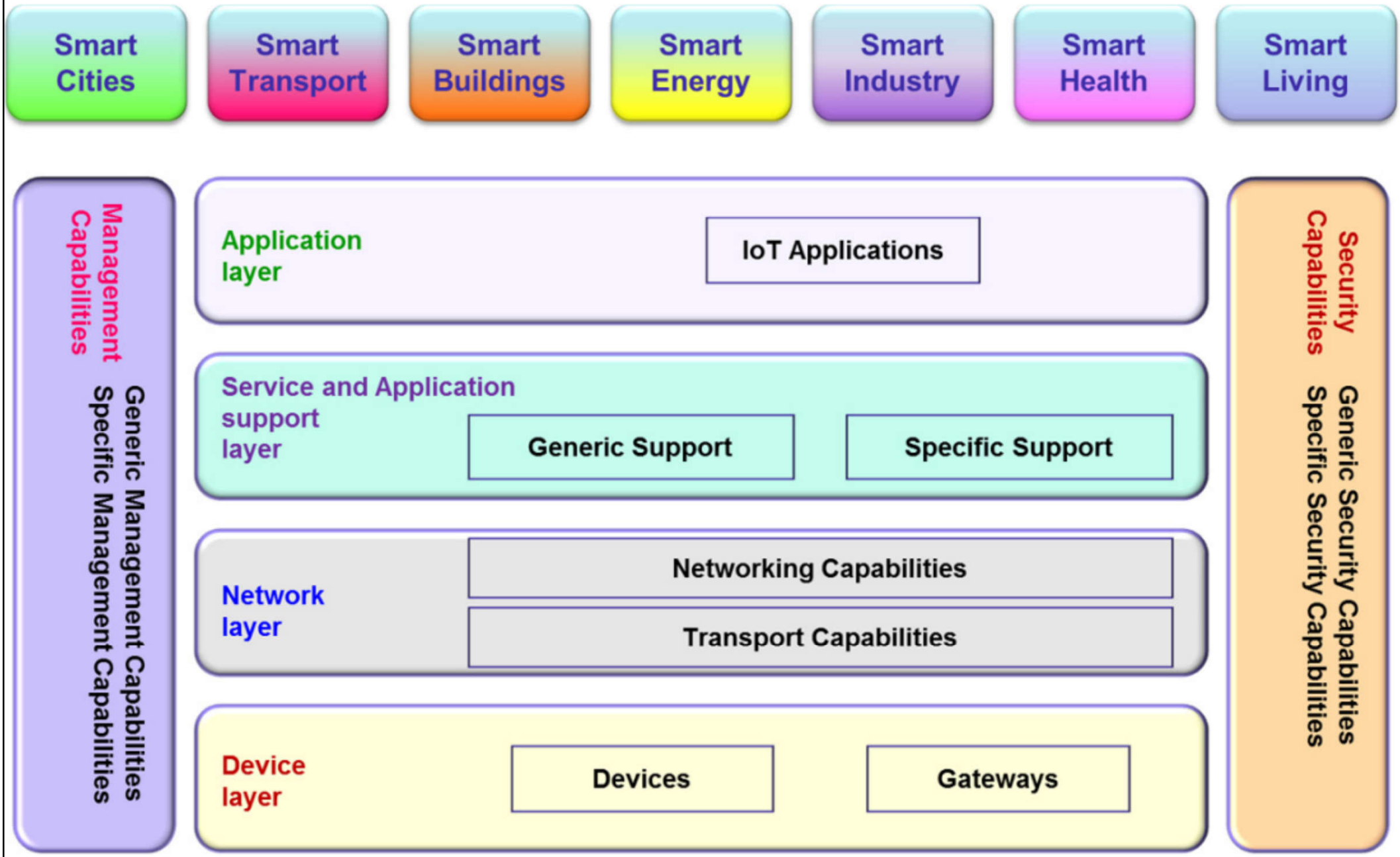
- Smart city IoT examples:
  - 1. IoT Public Transport – a network of IoT sensors to monitor traffic & improve public transport
  - 2. Smart Waste Management – improve waste collection, cleansing, detoxification & disposal
  - 3. Smart Street Lights – manage & control remotely to optimize power consumption
  - 4. Air Quality Monitoring – can alert air pollutants
  - 5. EV charging stations with IoT connectivity – ensure they are being used effectively

Generalized smart city layered architecture



(Source: Khalil U., Uddin M., Malik O. A. & Hussain S., 2022. A blockchain footprint for authentication of IoT-enabled smart devices in smart cities: state-of-the-art advancements, challenges and future research directions, *IEEE Access*, 10: 76805-76823. https://doi.org/10.1109/ACCESS.2022.3189998)

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



(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)

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

(Source: 8 IoT solutions in smart cities https://freeeway.com/8-iot-solutions-in-smart-cities/)

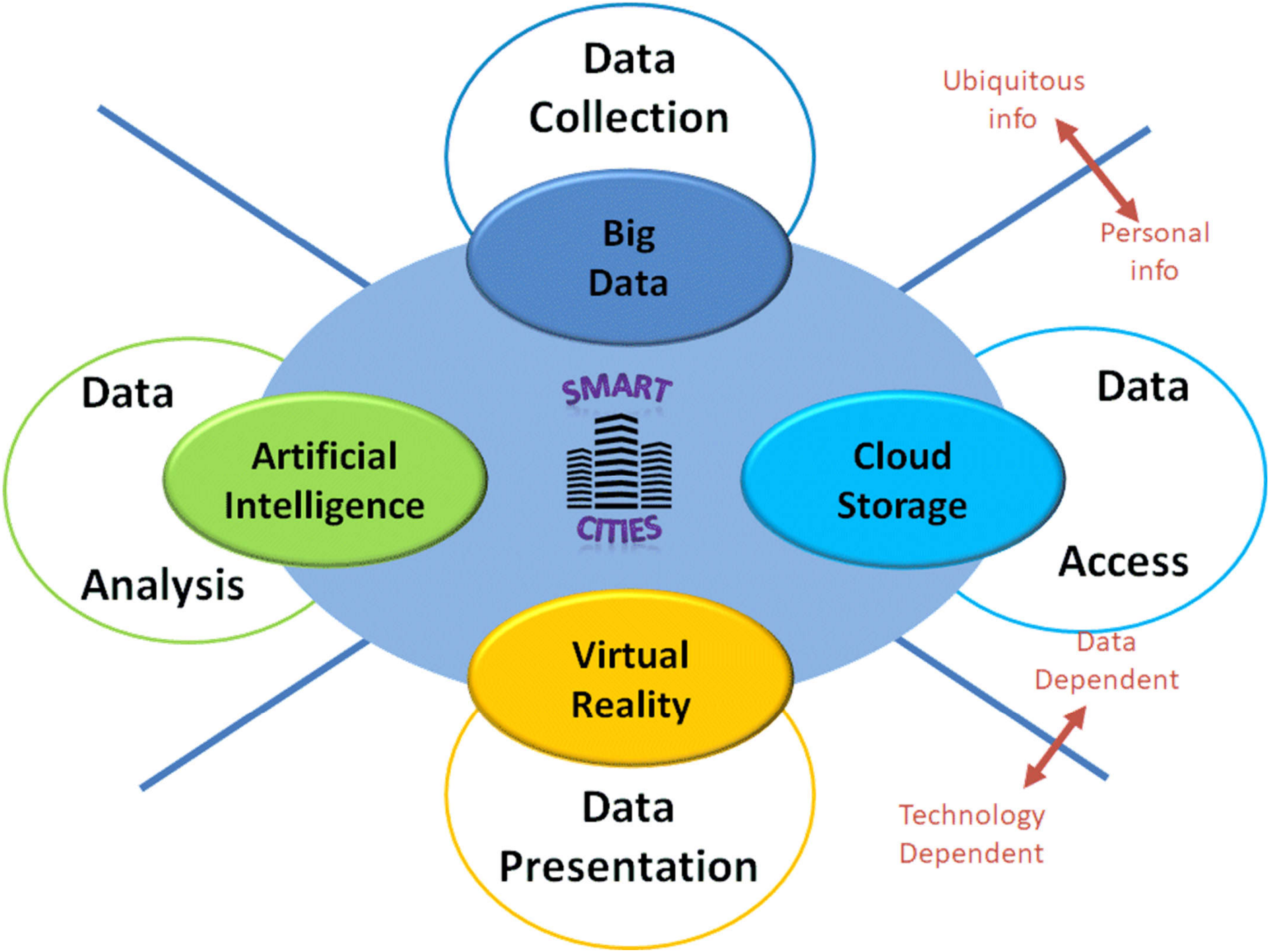
Smart environments & smart spaces creation

(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)

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



(Source: https://www.gdrc.org/u-gov/smartcities/)

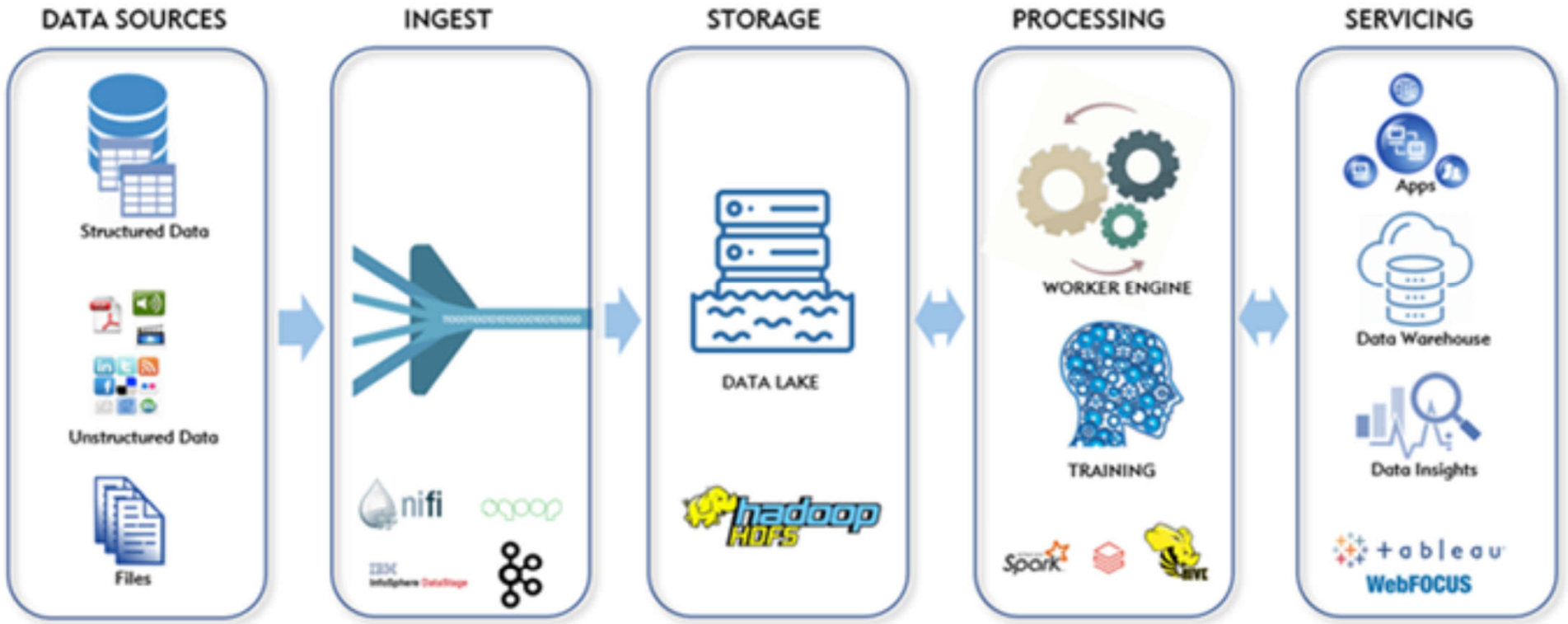
Smart city big data

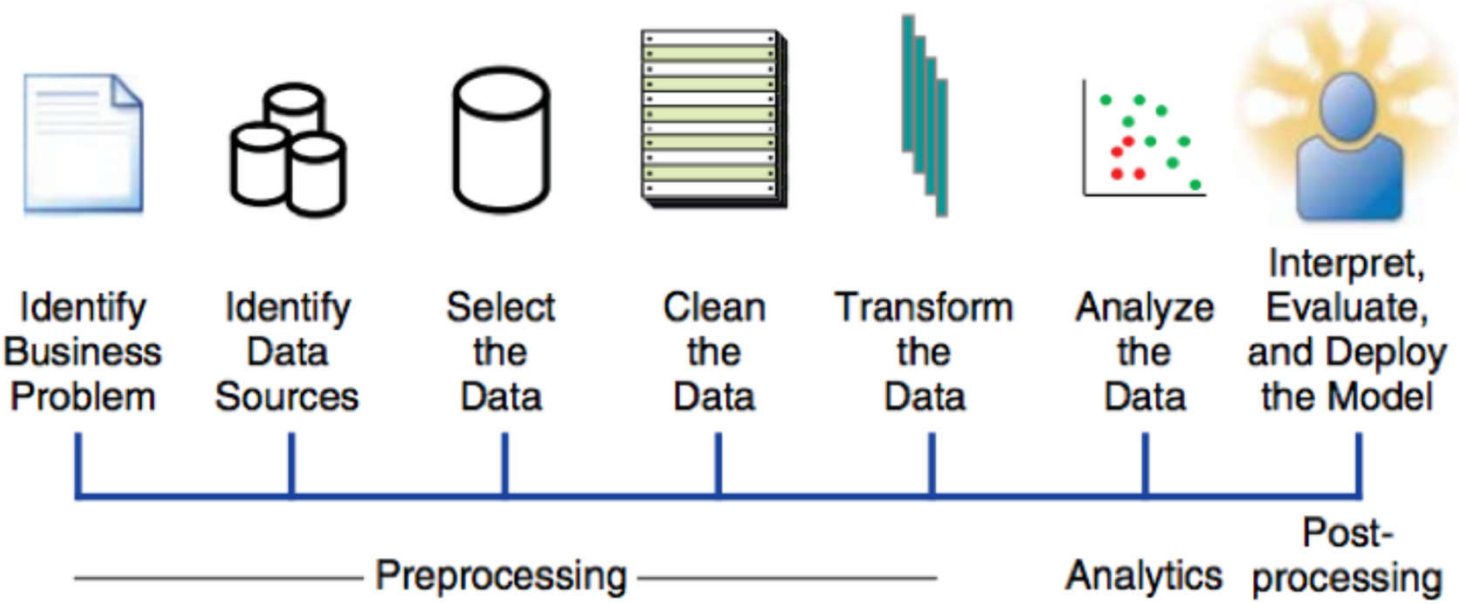
- A smart city uses sensors & connected devices to collect & analyze data to optimize city operations, manage resources & improve the everyday life of citizens
  - Enhance public transport & manage traffic
  - Improve smart urban lighting & reduce crime
  - Optimize water & power supply
  - Improve law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

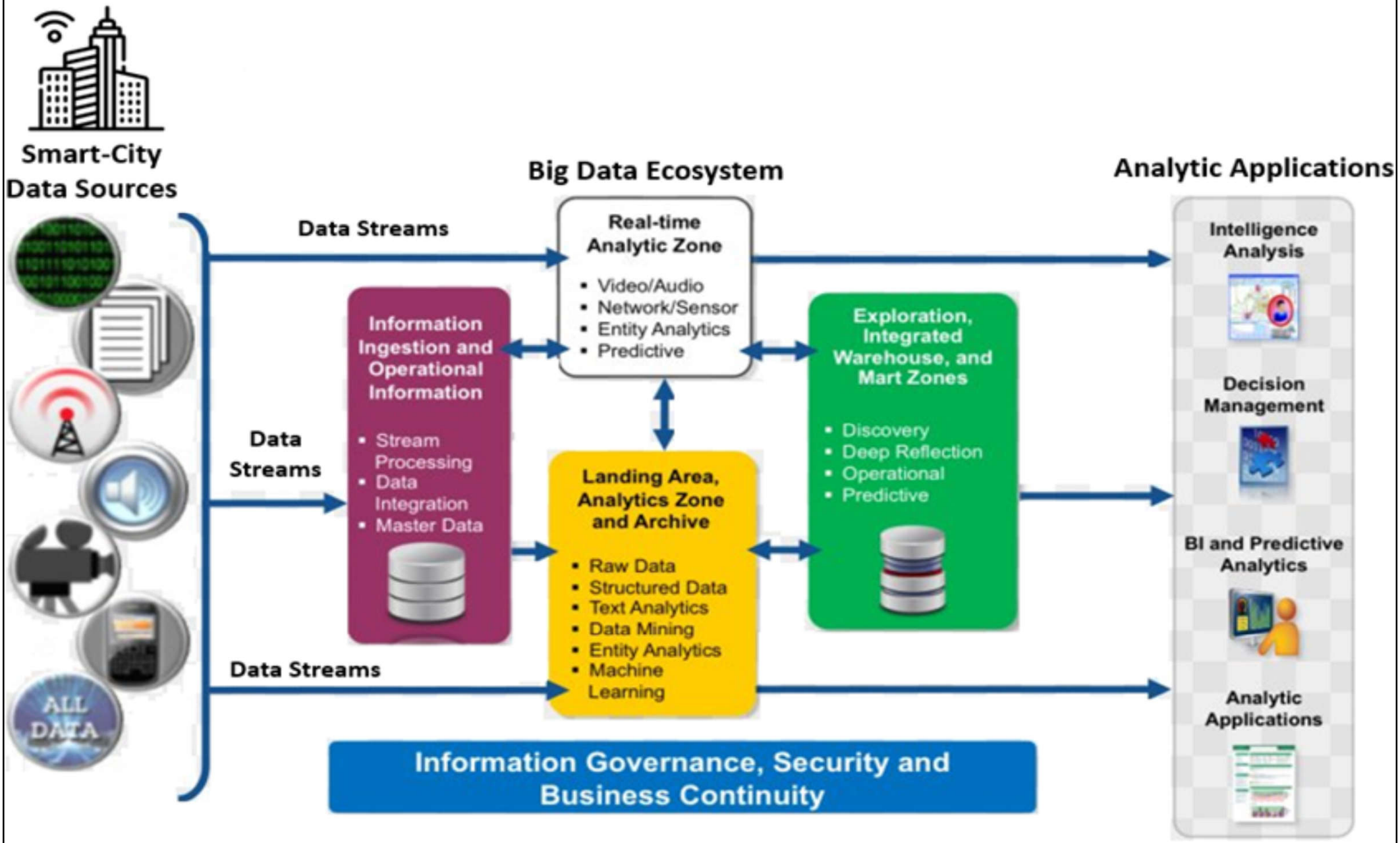
Smart city big data

- 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

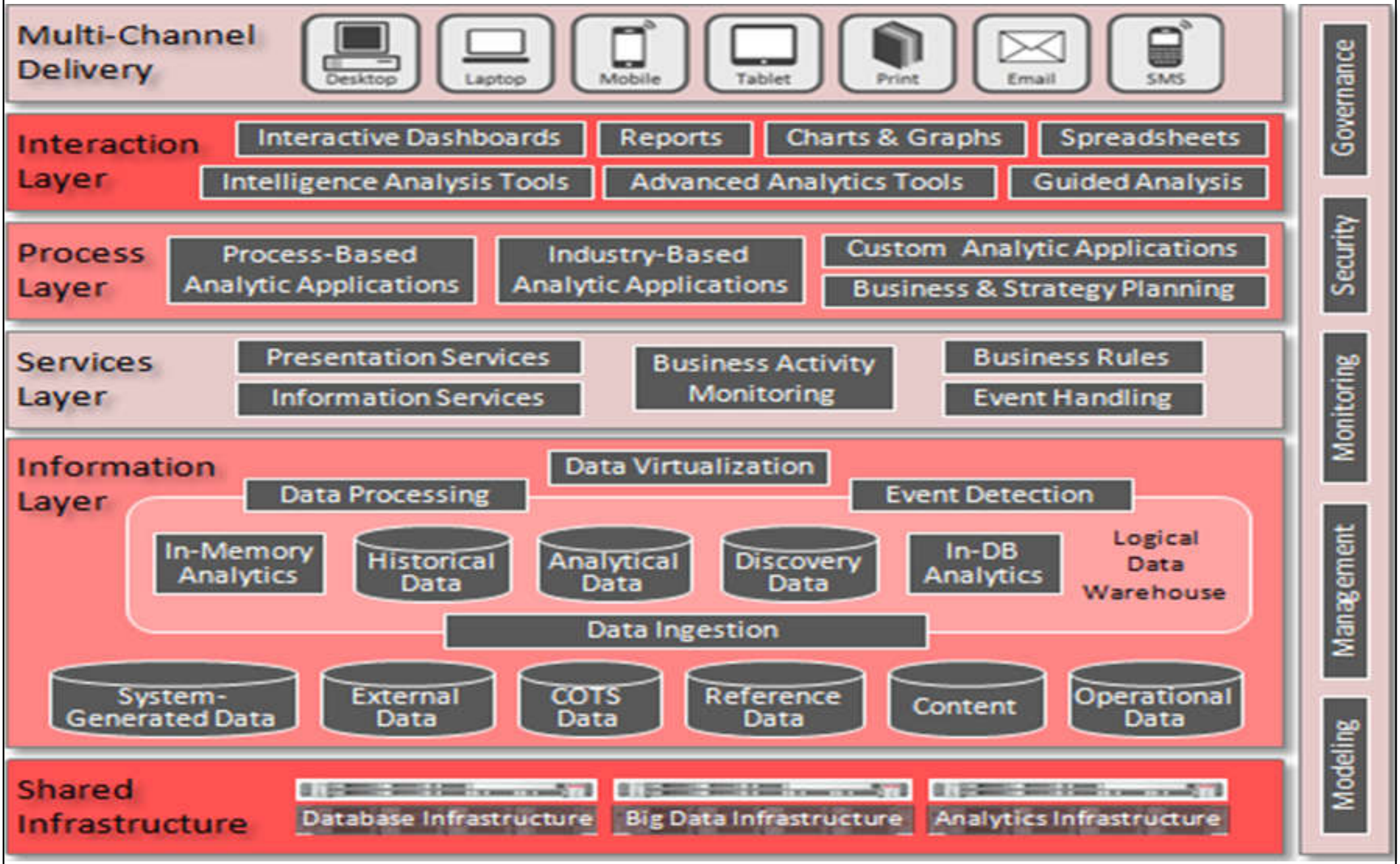
- Key challenges of smart city data analytics:
  - 1. Accessibility of data – Big data should be stored & maintained properly to ensure it can be used by less experienced data scientists & analysts
  - 2. Data quality maintenance – Requires significant time, effort & resources to properly maintain it
  - 3. Data security – The complexity of big data systems presents unique security challenges
  - 4. Choosing the right tools – 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



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

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. Availability – Data needs to be available in real time with reliable access
  - 2. Integrity – The data must be accurate & reliable, preventing manipulation from outside
  - 3. Confidentiality – Sensitive data needs to be kept confidential & safe from unauthorised access
  - 4. Accountability – 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/