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Internet of Things for Sustainable Human Health

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Chapter 7
Internet of Things for Sustainable Human Health

Abstract The sustainable health IoT has the strong potential to bring tremendous improvements in human health and well-being through sensing, and monitoring of health impacts across the whole spectrum of climate change. The sustainable health IoT enables development of a systems approach in the area of human health and ecosystem. It allows integration of broader health sub-areas in a bigger archetype for improving sustainability in health in the realm of social, economic, and environmental sectors. This integration provides a powerful health IoT framework for sustainable health and community goals in the wake of changing climate. In this chapter, a detailed description of climate-related health impacts on human health is provided. The sensing, communications, and monitoring technologies are discussed. The impact of key environmental and human health factors on the development of new IoT technologies also analyzed.

7.1 Introduction

The sustainable development goals (SDGs) are a set of goals established by United Nations (UN) following the millennium development goals (MDG), in 2015 by 193 UN member nations to address health, climate, and environmental issues being faced by the humanity [69]. These SDGs have laid a special focus on sustainable approach for future health and present a vital scope to foster the appropriate environment for an improved human health by the way of sustainable society. Thereof, four vital issues are identified [63].

- Necessity of systems approach for sustainable health
- Importance of health society for community's prosperity
- Assessment of climate change impacts and additional perils to sustainable health and to provide expeditious health benefits
- Development of indicators, models, and metrics to observe and project different health impacts in terms of threats and risks

To achieve SDGs objectives, a new systems paradigm is required across the various prongs of sustainable development (e.g., world, mankind, and well-being).

For this purpose, integration of sensing, communications, monitoring, and decision support systems is required for sustainable health IoT paradigm, under the guidelines of United Nations and World Health Organization.

7.1.1 Sustainable Health IoT

The sustainable health IoT enables development of a systems approach in the area of human health and ecosystem. It allows integration of broader health sub-areas in a bigger archetype for improving sustainability in health in the realm of social, economic, and environmental sectors. This integration provides a powerful health IoT framework to sustainable health and community goals in the wake of changing climate [31, 40, 87, 89]. The other climate mitigation approaches using the IoT paradigms also carry many health benefits such as health community is achieved via sensing and corresponding improvements in air quality, green urban environment, and reduction in flooding [14, 123, 146, 150]. The IoT paradigm also enables many health benefits of adaption and mitigation while providing insights climate-related health impacts [47, 86]. The climate change impact on human health is shown in Fig. 7.1 [153]. Because of this factor, either the current health problems become worse or new unparalleled health issues are generated.

The sustainable health IoT has the strong potential to bring tremendous improvements in human health and well-being through sensing, monitoring of health impacts across the whole spectrum of climate change. It is envisioned to provide health and environmental data that can be utilized to characterize the impacts of climate change on human health [47], which in turn enables identification, projection, and effective response to human health related threats. The impact of climate change on human health is discussed in the following section.

7.1.2 Climate Change and Human Health

A significant threat is being faced by the humanity in health related issues because of the climate change [15, 25]. The impact of weather and climate on human health is very significant and diverse. This exposure to climate induced health issues is impacting the community and people in different ways. There are many ways (e.g., environmental emissions, ozone exposure, water and air quality, temperature, and weather) in which human health is being impacted by the climate change [46, 50, 101, 109, 126, 160]. Particularly, the increasing concentrations of the carbon dioxide and rising temperatures, and their relation with variations in plants, flower production, and allergenic initiating time has led to increased production of the allergens [73]. The rise in emissions is also cause of rising temperatures and sea levels, variations in precipitation patterns, increase in extreme weather pattern.

	Climate Driver	Exposure	Health Outcome	Impact
Extreme Heat	More frequent, severe, prolonged heat events	Elevated temperatures	Heat-related death and illness	Rising temperatures will lead to an increase in heat-related deaths and illnesses.
Outdoor Air Quality	Increasing temperatures and changing precipitation patterns	Worsened air quality (ozone, particulate matter, and higher pollen counts)	Premature death, acute and chronic cardiovascular and respiratory illnesses	Rising temperatures and wildfires and decreasing precipitation will lead to increases in ozone and particulate matter, elevating the risks of cardiovascular and respiratory illnesses and death.
Flooding	Rising sea level and more frequent or intense extreme precipitation, hurricanes, and storm surge events	Contaminated water, debris, and disruptions to essential infrastructure	Drowning, injuries, mental health consequences, gastrointestinal and other illness	Increased coastal and inland flooding exposes populations to a range of negative health impacts before, during, and after events.
Vector-Borne Infection (Lyme Disease)	Changes in temperature extremes and seasonal weather patterns	Earlier and geographically expanded tick activity	Lyme disease	Ticks will show earlier seasonal activity and a generally northward range expansion, increasing risk of human exposure to Lyme disease-causing bacteria.
Water-Related Infection (*Vibrio vulnificus*)	Rising sea surface temperature, changes in precipi-tation and runoff affecting coastal salinity	Recreational water or shellfish contaminated with *Vibrio vulnificus*	*Vibrio Vulnificus* induced diarrhea & intestinal illness, wound and blood-stream infections, death	Increases in water temperatures will alter timing and location of *Vibrio vulnificus* growth, increas-ing exposure and risk of water-borne illness.
Food-Related Infection (*Salmonella*)	Increases in temperature, humidity, and season length	Increased growth of pathogens, seasonal shifts in incidence of *Salmonella* exposure	*Salmonells* infection, gastrointestinal outbreaks	Rising temperatures increase *Salmonella* prevalence in food; longer seasons and warming winters increase risk of exposure and infection.
Mental Health and Well-Being	Climate change impacts, especially extreme weather	Level of exposure to traumatic events, like disasters	Distress, grief, behavioral health disorders, social impacts, resilience	Changes in exposure to climate- or weather-related disasters cause or exacerbate stress and mental health consequences, with greater risk for certain populations.

Fig. 7.1 The climate change impact on human health [153]

Accordingly, water bodies are contaminated, diseases are transmitted through food sources, air quality is degraded, which, consequently, bring cascading adverse effects upon human health and well-being. These problems are being exacerbated with rapid changes hence increasing exposure of the human for longer duration of time [143]. Therefore, new challenges are being faced in the area of human health [45, 100]. The climate and holistic health outcomes are shown in Fig. 7.2.

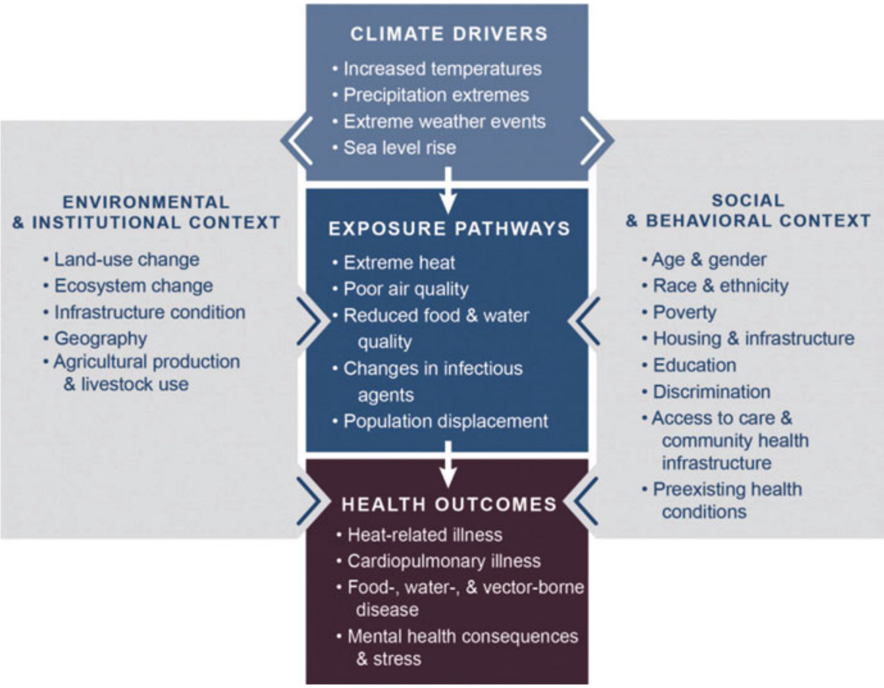

Fig. 7.2 The climate and holistic health outcome [153]

It is important to note that the magnitude of impact of climate on human health varies on spatial and temporal scale [72, 90, 119]. The children, elderly, poor, and sick are the ones most affected [10, 16, 79, 135, 140, 141]. The research has shown the high correlation between the mold and fungus related indoor air quality issues and the high and extreme temperatures, and heat waves and precipitation [48, 53, 64, 64, 75]. The moist indoor environment causes elevated prevalence of asthma and upper respiratory tract symptoms [2, 2, 39, 53, 70, 102, 128, 142, 148]. The extreme heat contributes to air pollution, and asthma, pediatric, deaths (e.g., hot cars), and increased frequency of emergency room (ER) visits, and hospitalization [7, 38, 91, 130, 159]. Similarly, the heavy precipitation also leads to severe flooding events, algal blooms, and waterborne diseases. The outdoor air quality is also affected by the wildfires which leads to respiratory issues because of smoke inhaling. The human health is also being impacted by the worsening air quality and pollution of the ozone [118]. The climate change has also led to expansion of scope of some disease vectors and other epidemiological factors, such as Ixodes ticks (Lyme disease vectors). The climate change also impacts the mental health and causes stress particularly after disasters and displacement. The summary of these climate change impacts is outlined below:

- The increased exposure to ozone [8, 15, 19, 50, 95, 125, 126, 151]
- Extreme weather events [1, 7, 52, 105, 116, 124]

- Rising allergens [108]
- Increase in frequency and intensity of wildfires [81]
- Thermal extremes [13]
- Growing harmful algal blooms (HAB) [9, 62, 114]
- Mental health stress [36, 57, 65, 66, 98, 106, 111, 145]
- Expansion of vector-borne infectious diseases [21, 83, 85, 93, 110, 117, 129, 136]
- More water- and food-borne diseases [32, 67, 88, 115]
- Food quality an security [56, 132]

7.2 Benefits of Sustainable Health IoT

The sustainable health IoT has tremendous potential to bring improvements in human health and well-being by enabling real-time sensing and monitoring of the climate induced impacts. These benefits are discussed below:

- Innovations in mobile health care
- Evolution of new sensing methods
- Novel communication techniques such as human body communications and molecular communications
- Remote diagnostic systems
- Human mobility models to predict diseases outbreak
- Support for remote telehealth and self-monitoring and tracking on diurnal basis
- Efficiency and improvements in health care settings
- Quick diagnosis of medical conditions
- Improvements in patient conditions management
- Development of novel treatment regimes

7.3 Sustainable Health IoT

The sustainable health IoT is characterized by its things which are the vital component of the paradigm for real-time sensing monitoring, medication compliance wireless communications, and imaging based decision support systems. In this section, the sustainable health IoT things are discussed.

- Patients, physician and health care providers
- Smart ingestible, implantable, and injectable medical devices
- Medicines, health, and wellness products
- Physiological, wearable, and molecular sensors
- Actuators, treatment, electronic health records
- Telehealth, precision medicine
- Insulin pumps, cochlear implants, and pacemakers
- Patient-generated and machine-generated healthcare data

7.4 Sustainable Health IoT Technology

In this section different technologies for sustainable health IoT are discussed.

7.4.1 Precision Medicine

The precision medicine is one of the emerging technologies in human healthcare [30, 96]. It deals with disease prevention and treatment approaches which are based on considering the human genetic, environmental, and other factors tailored to individual patients. The precision medicine practices are also called personalized medicine. The sustainable health IoT enables precision medicine by integrating DNA databases of clinical trials and application layer Health Level 7 (HL7) and other standards such as Fast Healthcare Interoperability Resource (FHIR) [120] to support treatments of different diseases.

7.4.2 Personalization of Diabetes Treatment

The sustainable health IoT also enables monitoring of the blood glucose levels in patients with diabetes [26]. By using sensing and wireless communications technologies, the advanced diabetes treatments can be utilized for extensive dissemination of blood sugar data to intelligent computing technologies and clinicians. There it can be evaluated for personalized treatment by generating prediction based cautions for insulin dosage and hypoglycemia updates.

7.4.3 Automated Nutrition Control

The sustainable health IoT enables automated nutrition control where based on daily calories needs, the customized food plan can be developed for patients by using the food ingredients. This enables suitable food choices based on the recommendations of the physicians. Accordingly, physicians can view the impact the food consumption on patient health for real-time decision making [61].

7.4.4 Mobile Healthcare Connectivity

The sustainable health IoT supports integration of wireless communications based interconnection of medical devices with the cloud for rapid on-line data management [144]. The Capsule Technologies Hub is a robust mobile gateway to provide connectivity using many different wireless interfaces [35, 167]. The mobile healthcare connectivity in sustainable health IoT enables development of healthcare applications based on the wireless technologies that enables patient management and coordination and leads to higher efficiency and decreased cost of medical care.

7.4.5 Cancer Treatment

Cancer treatment approaches can greatly benefit from sustainable health IoT monitoring and communication technologies, where patients can transmit updates through symptom tracking applications to their physicians [127]. The physician's response is helpful to reduce the frequency of regular clinic visits. Moreover, the side effects of the medicines can be identified and addressed quickly. Early warning can be issued when the levels cross a threshold.

7.4.6 Glucose Monitoring

The sustainable health IoT facilitates continuous glucose monitoring (CGM) in diabetic patients. IoT enables devices can continuously monitor the blood glucose levels by providing regular readings for subsequent transmission to cloud using wireless communications and Internet with easy access through mobile devices by patients and physicians [51]. Accordingly, the automated delivery of insulin enables efficient management.

7.4.7 Smart Inhalers

The smart and connected inhalers (Bluetooth spirometer [168]) in sustainable health IoT enable asthma and other chronic obstructive pulmonary disease (COPD) [133], which includes emphysema and chronic bronchitis) patients to take control of their symptoms and treatments by using Bluetooth. These can also send reminders to patient about their medicine intake, hence, improving the disease management, attack avoidance, and symptoms reporting to physicians.

Other important applications include connected contact lenses to monitor variations in eye dimensions causing the glaucoma [6]; the coagulation testing for blood clot formations to avoid stroke, bleeding [165], assisted living [122]. Overall, the sustainable health IoT enables, through its sensing, communications, and monitoring technology, efficient health care, drug and chronic disease management, and reduction in emergency room wait times.

7.5 Sensing in Sustainable Health IoT

In this section, two types of health related sustainable health IoT sensing approaches are discussed: (1) the physiological sensing and (2) the environmental sensing for health [138].

7.5.1 Physiological Sensing

The physiological sensing is a vital monitoring approach in the sustainable health IoT to measure and analyze different physiological (biological) signals for medical and clinical healthcare applications [29, 164]. These data collected from these physiological sensor signals is discussed in the following:

- Heart rate (HR)
- Finger temperature (FT)
- Respiration rate (RR)
- Carbon dioxide (CO_2)
- Oxygen saturation (SpO2)
- Patient position sensor (Accelerometer)

The sensors to detect these physiological signals are given below [11]:

- Glucometer sensor
- Body temperature sensor
- Blood pressure sensor (sphygmomanometer)
- Pulse and oxygen in blood sensor (SPO2)
- Airflow sensor (breathing)
- Galvanic skin response sensor (GSR—sweating)
- Electrocardiogram sensor (ECG)
- Electromyography sensor (EMG)

A detailed review of these physiological sensors is given in [11].

7.5.2 Ingestible Sensors

These sensors are ingested in capsules or pills and have the capability to dissolve in stomach [84]. There, these are used to sense different physical parameters, which can be communicated to the external nodes through human body communications or by using wireless communications. The legal issues in ingestible sensors are discussed in [60].

7.5.3 Wearable Sensors

Wearable sensors are placed into wearable objects to sense different phenomena such as health conditions, environmental conditions, and physiological signals [11, 27, 54, 161, 166]. These can also be implanted in body from where they can communicate using human body or molecular communications. Some important use cases of the wearable sensors are listed below:

- Wearable devices for environmental monitoring [94] such as air quality [20, 22, 28, 42, 80, 99, 137, 157, 158]
- Wearable AI system to detect a conversation's tone [155]
- Wearable devices for physiological sensing [76]
- Wearable system to help visually impaired users navigate [156]
- Monitoring metabolic energy expenditure, health, and fitness with a breath analyzer [112]
- Wearable sensor for athletes detects potential head injuries, gathers data on hard hits [18]
- Wristbands that keep wearers thermally comfortable [112]
- Wearable tracks increased skin conductance that signals stress, helps identify dangerous seizures [104, 149]
- Wrist watch to monitor depression, and Parkinson's disease symptoms [113]

7.6 Environmental Sensing for Health and Wellness

In this section, the sensing of different environmental parameters and their impact on human health is discussed.

7.6.1 Sanitation, Waterborne Diseases, and Human Health

The viruses, bacteria, and protozoa are major cause of waterborne diseases also called water-related illnesses. The human-induced chemicals, toxins generated by cyanobacteria, and detrimental algae, are other sources of some of these diseases [23, 131]. The patients are also exposed to these diseases when the contaminated water is inhaled or ingested. Other recreational activities in contaminated water and eating contaminated seafood are also a cause of waterborne diseases. The water-related illness grows, spreads, and becomes viral and toxic based on different climate related factors such as hurricanes, precipitation, runoff, and storm surges [32, 88]. Moreover, the exposure to these diseases also depends on individual's capacity of adaptiveness and sensitiveness.

Fig. 7.3 Water related health issues [153]

The waterborne diseases are also major challenge in urban areas where the 6–40% of gastrointestinal illness are caused by extensive contamination of wells and surface water by various pathogens. The access to safe drinking water is also a major global issue with one billion population lacking access to safe potable water. Moreover, the increasing global temperatures are fostering production of toxic algal blooms. These organisms are serious risk to human health (see Fig. 7.3) [153].

The sustainable health IoT through its sensing of water quality, real-time monitoring and warning systems, and other treatment technologies enables effective prevention and mitigation of diseases caused by water contamination. It enables water flow and quality monitoring. The water quality sensing also informs the selection of proper disinfection technique based on pathogen sensing and molecular sensing methods for specific pathogens and their ability to cause infection.

The sustainable health IoT holds great promise in water quality improvements and sanitation in less developed and advanced countries. Some examples are presented in the following:

- The smart meters and reverse osmosis (RO) technology in IoT systems and sensor networks is being used in India for provision of clean water and for water treatment to rural areas [134].

- The IoT technology is being used in China to monitor the water flow and usage by using sensors installed at different points in the water supply system [147].
- A biosensor network is utilized in Bangladesh for water quality monitoring using arsenic sensor [41].
- In Kenya, a smart connected water hand pump is being used to address the issues related to the non-functional water pumps for timely maintenance [92]. Special accelerometer based devices were designed and installed with built-in 3G radios for water hand pump monitoring. With battery life of up to 18 months, this IoT system has reduced downtime while ensuring consistent water supply service delivery.
- For sanitation and hygiene, the water flow and motion sensors are being used in Indonesia to identify human behavior (e.g., hand washing after toilet use) and to design enhanced hygiene training [152].

7.6.2 Ultraviolet Radiation and Human Health

The exposure to ultraviolet radiation (UV) can have multiple impacts such as corneal damage, skin cancer, sunburn, immune suppression, and cataracts [12]. The detrimental effects of ultraviolet radiation include damage to plastic, wood, and other infrastructure. Overall, UV radiation presents many challenges to health and environment.

The sustainable health IoT has the potential for robust monitoring of ozone and UV radiation levels at a large scale, which can be integrated to the cloud for new insights. Accordingly, models can be developed for informed decision making. A sensor called dosimeter determines the UV exposure by measuring absorbed amount of ionizing radiation. The ionizing radiation at its peak is capable of removing an electron from an item. A urocanic acid photoreceptor is used for the induction of UV immune suppression. The UV-induced (UVB induced) immune suppression is variation in cell immunity which produces suppressor cells. Various types of ultraviolet radiations and related concepts are discussed below [71]:

- UVA. The UVA has the longest wavelengths 0.31 micrometer to 0.4 micrometer and impacts skin aging. The ability of atmospheric gases to absorb UVA radiation is low. Therefore, UAV are able to reach surface of the Earth.
- UVB. It causes skin burning and suppression of immune system with its shorter wavelength of 0.28 micrometer to 0.31 micrometer. However, most of it is absorbed by stratospheric ozone.
- UVC. The UVC is mostly absorbed by the ozone and oxygen present in the atmosphere. It has shorter wavelength of 0.1 micrometer to 0.2 micrometer. UV-C radiation is almost entirely absorbed by atmospheric oxygen and ozone.

7.6.3 Extreme Weather and Human Health

The thunderstorms associated increased humidity levels are known to cause cardiovascular and respiratory diseases [44]. The natural disasters also contribute to the mental health issues (e.g., post-traumatic tension disorders). Moreover, the prolonged duration of the hurricanes, tropical storms, and extreme weather events also causes short-term stress related issues with its disruptions to subsistence activities and to different modes of transportation, affecting overall health and well-being.

7.7 Wireless, Human Body, and Molecular Communications in Sustainable Health IoT

The applications of wireless communication technologies to human health are being used for sensing, data collection, modeling, and analysis of health information of patients using Internet and various computing technologies [55, 59, 121, 162, 163]. Wireless communications play an important role to provide connectivity to sensors and system in sustainable health IoT in different topologies and configurations. The Bluetooth (IEEE 802.15.1) and Bluetooth Low Energy (BLE) are commonly used for this purpose due to its low cost and energy requirements along with other standards such 4G, WLAN, LTE, UMTS, Wi-Fi, and WiMAX. A list of different wireless technologies for sustainable health IoT applications is given below:

- IEEE 802.11x (Wi-Fi) is the widely used wireless local area network protocol for health applications. It operates in 2.4 GHz or 5 GHz frequency bands. The latest versions of the Wi-Fi can support data rates from 54 Mb/s to 0.5 Gb/s with communication range of more than 100 m [74].
- IEEE 802.15.1 (Bluetooth) operates in 2.4 GHz frequency band with communication range of up to 10 m. and supports data rates of 722 Kb/s for the classic version (BC) and 3 Mb/s for Bluetooth Enhanced Data Rate (EDR) [17].
- Bluetooth Low Energy (BLE) is a low power variant of Bluetooth. It can cover communication distances of up to 68m with maximum data rates of 1 Mb/s. It uses physical and data access layer of Wi-Fi.
- ZigBee (IEEE 802.15.4) is a less complex, low cost and data rate, wireless personal area network (WPAN) standard for prolonged operation of devices and equipment. It supports 868 MHz frequency, 915 MHz spectrum band, and 2.4 GHz radio wireless channel with maximum data rates of more 250 kb/s, respectively, for communication range of up to 75 m [169].
- Long range wide area network (LoRaWAN) has the potential for long range communications in sustainable health IoT applications (e.g., the LoRa) It also supports 868 MHz frequency and 915 MHz spectrum operation with data rates of more than 50 kb/s [37].

- Chirp spread spectrum (CSS) based nanoLOC operates in 2.4 GHz frequency band. It covers communication distances of up to 570m depending on the environment with data rates of up 2 Mb/s [139].

More details about wireless body area network can be found in [68].

7.7.1 Human Body Communications

The human body communications (HBC) is another important connectivity mechanism in the sustainable health IoT. Body is a highly conducting material (body tissues are lossy dielectric) because of the presence of the water and blood. Human body communications also are very energy efficient and require very low power for operation for implanted medical devices with long battery life, hence reducing the inter-surgery time significantly. Moreover, the human body communications are very secure and present resistance by preventing physical access of devices by hackers. These can be utilized to form the inter-body and body-to-body communication networks wearable sensors and devices, implanted medical devices, in-body authentication instruments in the sustainable health IoT [55, 58, 78, 107, 164].

The wearable sensors can establish connection using HBC for critical data communications to external devices. The body area network (BAN) in the IEEE 802.15 working group has developed a physical layer (PHY) for human body communications. In HBC, there are three main components: (1) the human body channel, (2) radio system, and (3) modulation and transmission schemes.

Another alternative to wireless body area network (WBAN) is electro-quasistatic human body communication (EQS-HBC) [34], which operates by broadband low frequency human body communications to achieve secure data transmission. A comparison of WBAN and electro-quasistatic is presented in Fig. 7.4.

7.7.2 Molecular Communications in Sustainable Health IoT

The molecular communications (MC) form the basis of the information transmission within basic unit of human life such as biological cells and complex organisms [4, 97]. In molecular paradigm, the data bits are modulated on molecules and communication propagation happens through the transport of these molecule and chemical reactions. The fundamental building blocks of the molecular communications are shown in Fig. 7.5 and are discussed below [4]:

- Molecules are the smallest distinguishable unit of a chemical compound and represent atoms bind together in the chemical composition of a particular substance [3].
- The chemical reactions are the manipulations and transformations resulting from the detachment and formation of molecules.

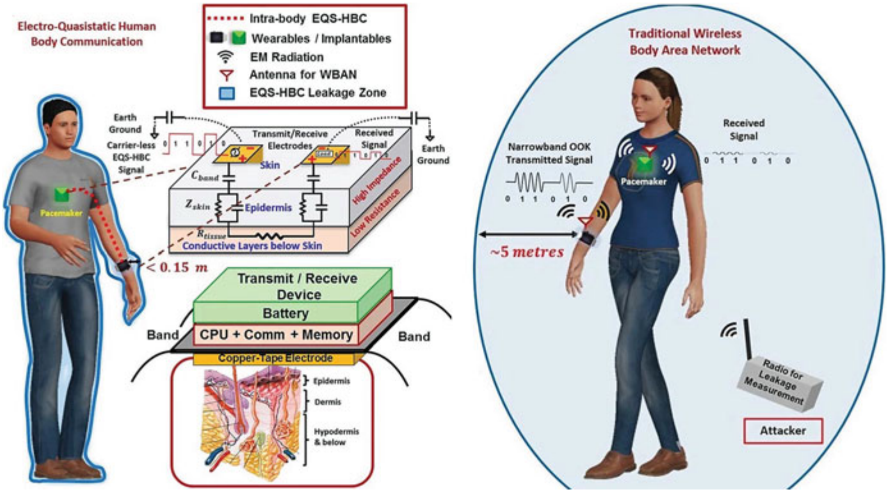

Fig. 7.4 A comparison of WBAN and electro-quasistatic human body communications [34]. EQS-HBC vs. WBAN: An Overview of the Data Privacy Space, (**a**) Persons wearing transmitter device (pacemaker) and an on-body hub communicating using EQS-HBC and (**b**) WBAN

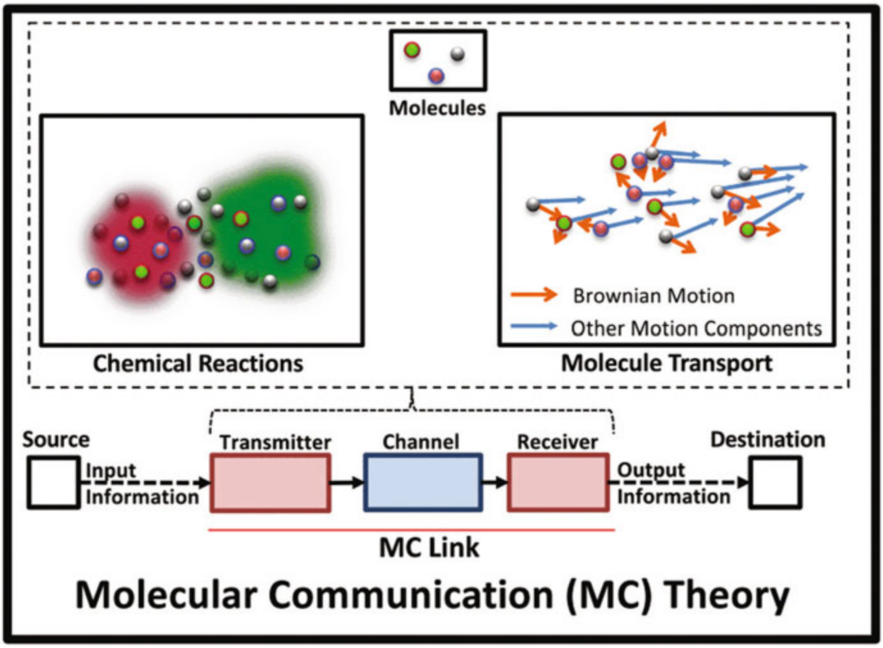

Fig. 7.5 The fundamental building blocks of molecular communications [4]. From moving forward with molecular communication: from theory to human health applications

- The molecule transport is the process of their propagation in space and happens through flow, transport, Brownian forces such as movement in the blood runnel or intra-cells motion [3].

The components of MC system include a transmitter, molecular channel, and a receiver. The communication channels propagation depends upon various molecular transport models such as chemotaxis, gap junction, diffusion, and molecular motor. The current research focus in MC is to maximize data communication rates, and development of coding and information modulation approaches, and the design of suitable modulation and coding techniques, and novel networking topologies for optimization of molecular data communication by molecules using multiple segments simultaneously [103].

The MC enables the sensing and monitoring applications through its propagation living organisms and the biochemistry underscoring the human body and cells (e.g., the cancers caused by the malformations polarity, and growth of molecules). The MC systems are envisioned to advance human health informatics and enhanced medicine with applications in natural and synthetic systems.

The monocular communications information flow theory in natural systems can model:

- At body scale, where a system is considered as an interconnection of tissues and organs.
- The cell coordination at cellular scale.
- The information modulation into compounds for subsequent propagation through chemical reactions and molecular transport.

For synthetic applications, the MC applications for system engineering purpose are:

- At interface level: Use of synthetic biology tools to develop genetic programs
- At device level: Development of bioengineering systems, programmed to perform specific actions.
- At network level: An interconnection of bio-engineering systems human health monitoring and connectivity to cloud

These applications of natural and synthetic systems of molecular communications in sustainable health IoT are shown in Fig. 7.6.

7.8 Sustainable Health IoT Systems

In this section, various systems, tools, databases, and indices to achieve sustainability using Internet of Things.

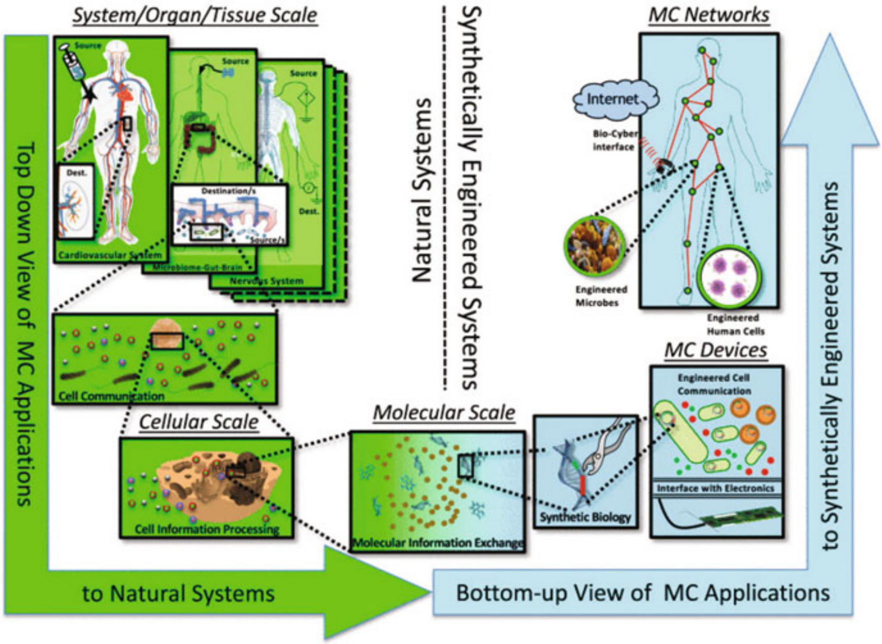

Fig. 7.6 Applications of natural and synthetic systems of molecular communications in sustainable health IoT [4]. From moving forward with molecular communication: from theory to human health applications

7.8.1 Health Indices

The vital health indices related to the environment are discussed:

- UV Index. This index is used to predict the solar UV radiation. The UV index is a number, measured on a scale of 0 to 11, that reflects the diurnal threat of sunburn (over-exposure to sunlight). The value of 0 represents the minimal exposure and an index value higher than 10 indicates extreme risk to human health [154].
- Environmental Health Hazard Index. The US environmental health hazard exposure index provides information about harmful toxins exposure neighborhood levels [49]. These health hazards exposures are determined using linear combinations of estimates of air quality respiratory, carcinogenic, and neurological hazard with indexing census tracts.
- AirNow: The air quality index (AQI) is an index to monitor the air quality and pollution. Accordingly, it informs about the related impact concerning human health [5]. It is ascertained by considering four air pollutants: particle pollution, carbon monoxide, surface ozone level, and sulfur dioxide gas.

7.8.2 Environmental Public Health Tracking Network

This US tracking network contains data and information on health effects, environmental hazards and substances, and human health [24]. This is an important data source for measuring hazardous substances in environment. The main features of the environmental public health tracking network are outlined in the following:

- It provide insights about spread of these substances over spatial and temporal scale and their impact on human tissues (e.g., carbon monoxide and air pollution in the environment).
- It also hosts data about health conditions and diseases, such as asthma and birth defects.
- It also contains exposure data. It contains vital information about the exposures relationship with the health effects, which relates specific health problems to age, race, sex, and behavior and lifestyle choices.

7.8.3 Mobile Health-Care Innovations

The mobile technology is an emerging innovation in healthcare solutions. Mobile applications are being developed to address mental health, cancer, active sports therapy, and rehabilitation with capability to support large-format displays, Bluetooth pen, AI, and cameras. These mobile technology when integrated with sustainable health IoT holds massive potential to make a profound impact by providing valuable healthcare services, such as telehealth [77], virtual care, and remote patient monitoring.

7.8.4 Mobility Models and Health

The human mobility models are used to analyze the population movement which can be used to mitigate disease outbreaks (e.g., development of malaria eradication strategies) [43]. During the 2014 Ebola outbreak in Sierra Leone, Guinea, Nigeria, Liberia, and Senegal, the call detail records (CDRs) from mobile cellular wireless network were used to monitor population movements through development of epidemiological models. These mobility models were used to forecast the spread of Ebola and potential outbreak of disease through analysis of movement paths of the affected population. The privacy concerns and security related issues are some of the major challenges in implementation of this approach in sustainable health IoT [82].

7.8.5 Virtual Beach

This virtual beach is a decision support system to predict disease-causing pathogens at beached. The policy makers can utilize the statistical model for health related beach decisions. It is also to issue alerts about the concentrations of fecal indicator bacteria (FIB) concentrations observed at beaches [33].

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