Home Taxonomy & Levels of Automation

Recent developments in the domain of Internet of things (IoT) and information and communication technologies (ICT) are transforming homes into interconnected ecosystems of smart technologies and services. However, the discourse on home technologies and services remains fragmented. Inconsistent terminologies for similar products and functions have impacted consumer technology literacy in this domain and been recognized as a barrier in consumer adoption of existing products. Consumers have limited knowledge regarding many new smart home technologies and industries. Additionally, unlike other domains such as aviation and surface transportation, the "smart home" does not have an established and widely accepted framework that describes different levels of automation.

This taxonomy aims to bring attention to the absence of such a framework by addressing the following questions: What is a smart home and how are smart homes different from non-smart homes? What are the possible paths and directions for future smart and connected homes? What are the important factors that differentiate various types of homes with different levels of automations?

This taxonomy seeks to provide a universal set of definitions for current and future smarter homes. With a more consistent vocabulary to express levels of automation, a consumer can know what to expect when they purchase a smart home product, and technologies would be designed based on discrete levels of home taxonomy. Moreover, as seen in other domains, e.g., transportation, a smart home taxonomy would facilitate standardizations and regulations by providing a conceptual framework for policymakers. Finally, our proposed taxonomy aims to facilitate communication across disciplines, among researchers, designers, and developers, by providing a shared vocabulary for them to describe smart home products and their functions.



Level 1 Traditional Homes

The majority of homes around the world today are Traditional Homes.

Traditional Homes include technologies with pre-determined functions.



- Technologies in Traditional Homes have predetermined functions which do not actively adjust to user needs.
- Devices in these homes can only receive and act upon inputs (stimulus-action response). They do not have decision-making abilities.
- Traditional Homes do not possess technologies that can understand resident needs. There is no monitoring of the environment, users, user habits, user status, or in-home activities.
- In Traditional Homes, in-home technologies are connected to each other only through electrical wiring; no wireless radio communications are involved. Such technologies mostly operate independently, while some tightly-coupled devices (e.g., a motion sensor and ceiling light) may be deployed and operate together.
- In terms of connection to outside services, Traditional Homes are mostly connected to public utility services. However, smartphones have opened ways to connect residents with services such as online deliveries.



Level 2 Customizable Homes

Customizable Homes have been widely adopted during the last decade.

Customizable Homes include technologies with programmable functions and customization features.

- In Customizable Homes, there is at least one technology that residents can customize, personalize, or program based on their needs. "If-else" features, programmable routines, and recommendation engines are some examples of customization tools.
- In-home devices that are "customizable" provide interfaces through which they can receive contextual information or action requests from other devices.
- Customizable Homes have incomplete monitoring systems and a partial understanding of user needs; i.e., an understanding that is only relevant to some tasks through one or a few in-home technologies.
- Customizable Homes are widely connected to public utility and delivery services. During the last decade, basic connections of in-home safety, energy, health, and assistive systems to safety departments, local communities, and healthcare providers have emerged in some homes of this level as well.





Level 3 Networked Homes

Networked Homes are becoming increasingly popular.

Networked Home are platforms of user-programmed connected devices.



- In Networked Homes, a richer connectivity among different devices is accomplished based on interoperability solutions supporting seamless primitive data communications.
- In-home devices are connected through either wired (e.g., Ethernet) or wireless communication (e.g., WiFi, Bluetooth, Zigbee, InfraRed, etc.) technologies. Devices can discover each other and establish a network when requested by the user.
- Users can set rules for their devices through a central home gateway (e.g., turn on lights upon arrival, turn on coffee machine when waking up) according to their needs. As more devices are coordinated, users can define more sophisticated home automation logic.
- O Devices do not have the capability to learn about the environment and/or user. Therefore, Networked homes may have a limited understanding of individual user needs. Basic responsiveness to the in-home environment and/or the residents can be achieved by customization rules.
- Networked homes are vastly connected to utility and delivery services. Due to higher interconnectivity among in-home devices, connection of in-home safety, energy, health, and assistive systems to outside services can be more highly automated due to enabled connectivity features e.g., the car battery charger is connected to the resident's calendar.





Level 4 **Proactive Homes**

Proactive Homes are near-term futuristic homes.

Proactive Homes are platforms of devices with awareness to current status of individual users.



- In Proactive Homes, the majority of technologies are connected to each other to work together beyond primitive data transmission. An advanced level of interoperability is intended to advance the technological system's awareness of the environment and/or its users.
- In Proactive Homes, a central intelligence (e.g., home gateway, cloud service, etc.) or in-home devices may have enhanced awareness of the environment, users, their habits, status, and activities. Such enhanced awareness might be achieved based on a holistic and/or longitudinal view of in-home situations and probabilistic methods including machine learning.
- According to the home (network) configuration, the centralized intelligence can also be realized by orchestrated distributed smart devices (e.g., multi-agent user preference learning).
- Proactive Homes are vastly connected to utility and delivery services. Due to a higher level of interoperability among in-home devices, connection of in-home safety, energy, health, and assistive systems to outside services are more efficient, enhanced, and tailored to multi-resident homes and sensitive to users' lifestyles.





Level 5 Companion Homes

Companion Homes are futuristic homes.

Companion Homes are platforms of devices with awareness of the current and future status and needs of individual users.



- Companion Homes are capable of understanding users' emotions, perceiving hidden needs, predicting unseen situations, taking actions, and making suggestions.
- Companion Homes can contain one or more physical entity that can manage all physical tasks and chores. The physical entity could be comprised of an array of existing in-home technologies or a separate entity like a social robot. The support that this entity provides encompasses both practical tasks and social and emotional companionship.
- Companion Homes at this level are vastly connected to outside services and emerging smart cities and regions in many countries. High-level interoperability among the in-home devices orchestrated through distributed AI and awareness of environments and individual residents provide meaningful information to external parties such as local public safety, the city-wide housing grid and local authorities, transportation services, healthcare providers, and insurance companies for the efficiency of services.



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