‘’’The proposed hybrid crowd sensing is defined as ‘‘a community sensing paradigm leveraging both the high reliability and performance of static devices and the large-scale, cost-effective mobile devices in a smart, connected environment’’. Following this definition, its conceptual framework for manufacturer/service provider-user value co-creation is proposed, as shown in Figure 2. It mainly consists of four layers, i.e. physical resource layer, hierarchical data collection layer, service composition layer, and service application layer, conducted in a platform-based data-driven manner. Physical resource layer, consists of various SCPs, including both mobile devices (e.g. smart phones, wearables, etc.) and static sensing devices (e.g. machine tool equipped with RFID tags). Each device is assigned with a universal unique identifier (UUID) for easy identification and retrieval. Both serve as the main data collectors, and different stakeholders (e.g. manufacturer, service provider and customer) participated in the sensing task with massive user-generated (e.g. service record) and product-sensed (e.g. failure mode) data in a connected environment. For cases, industrial devices (e.g. assembly line) can communicate with mobile devices (e.g. smart phones) through specific communication protocols (e.g. OPC Unified Architecture) so that information can be otherwise collected by the mobile devices alone as the wireless terminals. Heterogenous data collection layer includes both user-generated online data (e.g. ratings, text feedback) from MSN and/or online communities as social sensors and user/product-sensed offline data (e.g. location, acceleration, pressure) from built-in sensors and/or sensing data from other connected devices as hardware sensors. Meanwhile, other reliable existing data sources (e.g. product-service information, service records, etc.) should be considered as well. In return, the service providers should give certain incentives to the effective contributors. The wireless data sensed can be submitted to data collectors via access to macro base stations (MBSs) or submitted through little access points (LAPs), such as micro base stations and relay stations from nearby data collectors deployed by manufacturer/service providers . The LAPs work as the middleware to not only receive data, but also pre-process it (e.g. filtering, cleaning) before submission to the data collectors. Nevertheless, due to the limited sensing coverage of LAPs, large-scale mobile devices can also act as temporary relay stations for relaying data collected to the LAPs. Service composition layer, is responsible for generating novel service concepts, and managing encapsulated services based on request. It is mainly composed by the intelligent system platform established based on the state-of-theart cloud computing, knowledge-based systems (KBS) and AI techniques. Cloud computing enables ubiquitous access to a shared pool of configurable system resources and higher-level services of end users in a ‘‘pay-per-use’’ business model [50]. It has the advantages of agility, scalability, high-performance computing, social media support, ubiquitous access multi-tenant etc.where service providers/manufacturers in the Smart PSS can achieve abundant design information without capital investment in the IT infrastructure. Meanwhile, by leveraging KBS and AI techniques, valuable knowledge can be extracted, and further analysed from the big data. Service application layer includes both e-services and digitalization service for uses’ applications (i.e. service consumers). E-services stands for the ones that has little dependent with the product itself, e.g. the mobile APP for weather forecasting or industrial news subscriptions. Meanwhile,digitalization services represent the ones that are largely dependent, e.g. smart maintenance services of the product. In the Smart PSS context, these smart services as add-on values, are delivered to the customers by embedding them in the SCPs in an interconnected manner. Hence, the design of Smart PSS can be conducted in a circular manner with sustainability concerns.

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Q:What is an Intelligent Product Service System?

A:Product-Service System (PSS) is a systematic design concept that combines products and services. Smart Product-Service Systems usually integrate smart technologies (e.g., IoT, AI, cloud computing, etc.) to achieve a seamless connection between products and services, thus providing a more comprehensive, personalized and flexible user experience. Such systems not only provide physical products, but also include value-added services related to them, forming a new business model.

Smart Product: This refers to products with self-awareness, self-adjustment, data analysis and remote control capabilities through embedded sensors, computing power and networking capabilities.

Services: Through product data collection, real-time monitoring, predictive maintenance, and personalized recommendations, services tailored to user needs are provided to optimize the product experience.

The key to the intelligent product service system is to combine products, services and intelligent technologies to extend the product life cycle, improve service quality, and realize efficient resource management and customer value creation through digital means.

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Q:Principles of Intelligent Product Service System

A:Smart Product-Service Systems (SPSS) are the integration of products and services through the application of smart technologies in order to provide a more efficient, personalised and optimised user experience. Such systems usually involve multiple components, including hardware, software, data analytics, and service delivery, so their design and implementation need to follow some basic principles. The following are some of the core principles:

1. User-centred design: Intelligent product service systems should be centred on user needs, and the design process must provide an in-depth understanding of user needs and expectations. This includes collecting and analysing user data through user research such as interviews, observations and prototype testing.

2. Sustainability: System design should consider environmental impact and resource efficiency, promote the use of renewable resources, reduce waste and pollution, and achieve both economic and environmental sustainability.

3. Intelligent Integration: Intelligent technologies, such as Internet of Things (IoT), Artificial Intelligence (AI) and Big Data analytics, should be integrated into products and services to enable efficient data collection, analysis and application to optimise operations and user experience.

4. Security and privacy protection: user data security and privacy must be strictly protected when designing and implementing smart product and service systems. This includes the use of encryption technology, strict control of data access rights, and compliance with relevant laws and regulations.

5. Modularity and Flexibility: The system should be designed to be modular so that it can be quickly adapted to changes in the market and technology. The modular design also supports customised services and product extensions or upgrades.

6. Collaboration and ecosystem building: The success of a smart product-service system often depends on cross-industry collaboration and a healthy ecosystem. Partners include suppliers, distributors, technology providers and other stakeholders working together to create greater value.

7. Continuous Learning and Improvement: Intelligent product service systems should be designed to continuously learn and improve as technology evolves and market needs change. User feedback and system performance data are used to continuously adjust and optimise system functionality.

These principles provide a solid foundation for the design and implementation of intelligent product service systems, ensuring that these systems effectively meet user needs while improving economic and environmental performance.

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