

A Tool Rental Service Scenario

IoT technologies enabling a circular economy business model

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Abstract—Internet of Things (IoT), sensors, wireless networks, cloud computing and big data analytics are technological innovations that have the power to transform traditional businesses. These technologies can enable and accelerate a circular economy on a broader scale. We aim at providing information on how to disrupt current prevailing linear business models by employing digital data and IoT technologies. We give the reader a short overview of IoT technologies affecting the incumbents of industry. We present the current deployment of a tool rental service experiment and develop a scenario anticipating the possible future of the tool rental service. The envisioned tool rental scenario provides understanding on the effects of digital technologies and helps companies in identifying more sustainable and circular business models.

Keywords—circular economy; IoT; scenario; tool rental service; sensors; networking; cloud computing; data analytics.

I. INTRODUCTION

The concept of a circular economy describes an economy with closed material loops. The circular economy focuses on reusing materials, and creating added value in products through services and technology-enabled smart solutions. This implies that the concept of the circular economy is a continuous development cycle that aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles [1]. If EU manufacturing sector would adopt a circular economy business model, net material costs savings could worth up to 570 billion euros per year and growth opportunities 320 billion euros by 2025 [1][2]. The circular concept fosters also wealth and employment generation against the backdrop of resource constraints [3][4]. This transformation from linear “take-make-dispose” economy to circular one requires disruptive innovation in business models and technologies.

The Internet of Things (IoT) is considered as being one of the key enablers for enhancing the circular economy at large [2]. We define IoT as a computing concept where internet enabled physical objects (e.g., sensors, actuators, tags, smart machines) can network and communicate with each other to achieve greater value and services by exchanging data and producing new information [5][6]. IoT relies on the three pillars related to the ability of smart objects: i) *to be identifiable*, ii) *to communicate* and iii) *to*

interact. When object can sense the environment and communicate, they become tools for understanding complexity and responding to it [5].

Advancement in IoT technologies is making the current linear take-make-dispose economy more and more efficient, but still fails to address resource and natural capital issues. However, this new connectivity between emerging technologies and economy also offers the opportunity to re-think the underlying system and support the development of a circular economy. By combining the principles of circular economy with IoT technologies, there may be greater opportunity to scale new business models more effectively [7].

In this paper, we will present a circular economy based tool rental service scenario. First, we take a look at the main principles of circular economy in Section II. Then, in Section III, we present an overview of potential IoT technologies enabling the circular economy business. In Section IV, we describe the current deployment of the tool rental service, as well as develop the scenario for the future developments. Finally, Section V concludes the paper and provides some indicators for future work.

II. CIRCULAR ECONOMY

A circular economy is commonly defined as an industrial system that is restorative or regenerative by intention and design [8][9]. In the circular economy, new business models are developed to reduce the need for virgin raw materials and to generate sustainable growth. The basic approach of the circular economy is to eliminate waste by designing out of waste. Products are designed and optimized for a cycle of disassembly, reuse and refurbishment, or recycling, with the understanding that economic growth is based on reuse of material reclaimed from end-of-life products rather than extraction of resources. Circular design makes products easier to disassemble in preparation for their next round trip. Reuse means the use of a product again for the same purpose in its original form or with little enhancement or change. Refurbishment means a process of returning a product to good working condition by replacing or repairing major components that are faulty or close to failure, and making ‘cosmetic’ changes to update the appearance of a product, such as cleaning, changing fabric, painting or refinishing. Any subsequent warranty is generally less than issued for a new or a remanufactured product, but the warranty is likely to cover the whole

product (unlike repair). Accordingly, the performance may be less than as-new. [1].

In a circular economy, the concept of *user* replaces that of *consumer*. Unlike today, when a consumer buys, owns and disposes of a product, in the circular economy, durable products are leased, rented or shared whenever possible [1]. If goods are sold, new models and incentives motivate consumers (users) to return or reuse the products or their components and materials at the end of their primary use. New performance-based business models are instrumental in translating products designed for reuse into attractive value proposals. IoT technologies and digitalization in general have potential to disrupt current prevailing linear business models [10]. For example, the incumbents of the media and music industries have bitterly experienced the enormous forces of start-ups' new business models based on digital data and IoT technologies.

III. ENABLING IOT TECHNOLOGIES

The concept of combining computers, sensors and networks to monitor and control devices has existed for decades [11]. The recent advances in digital technologies are not only limited to embedded technologies, wireless communication protocols and small devices, but also huge amounts of data are being generated and can be utilized to improve businesses. In this section, we give a short overview of the potential IoT technologies affecting the circular economy.

A. Sensors

Recent advances in wireless technologies and electronics have enabled the development of low-cost, low power and multifunctional sensors that are small in size and can communicate in short distances. Typically, these sensors consist of sensing, data processing and communication components. The deployment of sensors is mainly driven by three factors; decreasing price, improving computational power and smaller size, which enables their integration into smartphones and other small devices [12].

Sensors are often categorized based on their power sources, i.e., *active* or *passive*. Active sensors emit energy in environment, while passive sensors passively receive energy that is produced externally to the device. Passive sensors require less energy, but active sensors can be used in harsh environmental conditions. Sensors can measure for example a position, motion, pressure, temperature or humidity of a device or surroundings [13].

B. Networking

Data collected with sensors need to be communicated to other locations for integration and analytics. Internet Protocol (IP) is an open protocol that provides unique addresses to various Internet-connected devices. IP networking represents a scalable and platform-independent technology having interoperability as the most essential objective. There are two IP versions, IP version 4 (IPv4) and IP version 6 (IPv6), which is the next generation protocol designed to provide several advantages over IPv4 [14].

Network technologies can be classified as wired or wireless. The main advantage of a wireless network is that users and devices can move around freely within the area of the network and get an internet connection, while wired connections are still useful for relatively more reliable, secured and high-volume network routes. The choice of technology depends mostly on the geographic range to be covered [15].

The most common short-range wireless network technologies are Bluetooth [16], Near Field Communication (NFC) [17], Radio Frequency Identification (RFID) [18], Wi-Fi [19] and ZigBee [20]. Respectively, the most commonly employed wide range wireless network technologies are cellular technology, such as 3G or 4G, and Low Power Wide Area Network (LoRaWAN) [21].

C. Cloud-based platforms

An IoT platform enables interaction between devices and users. With cloud technology, platform's computation and storage resources can be made available on a need basis, without requiring major investment in new hardware or programming.

Many vendors, such as Microsoft, HP, IBM and Oracle, provide commercial cloud-based IoT platforms for connecting sensors and actuators to the Internet. In addition, several open-source IoT platforms are available and often propose their own communication or middleware solutions. Reference [22] gives an evaluation of a number of available proprietary, as well as open-source, IoT platforms.

D. Data integration

Data communication includes a set of protocols that have been built for high volumes and large networks of assets. The most of IoT platforms are implemented with the Representational State Transfer (REST) API, which also enables an easy integration with other web services [23].

Constrained processing capabilities and limited battery resources restrict communication in sensor systems. Typical sensor application and data communication protocols considering processing capability and energy consumption are REST-based Constrained Application Protocol (CoAP) [24], Message Queue Telemetry Transport (MQTT) [25], and Extensible Messaging and Presence Protocol (XMPP) [26].

Data processing methods can be divided in two categories. *Batch processing* starts with data acquisition and storing and continues with processing of already stored information. Apache Flume [27] focuses on a flexible architecture, enabling the use of a variety of data sources and sinks. Another example of getting the data and sending it somewhere else at very large scale is Kafka [28].

Especially new IoT applications require real-time processing of information, where data items are processed as soon as they become available. This is called *stream processing* and it facilitates real-time action on the data, as well as filtering and aggregating it for efficient storage. Some new frameworks, such as the Apache tools Samza [29], Storm [30] or Flink [31], have been created for tackling the real-time processing of streams of information.

Performance and scalability requirements shift the choice of data storage towards column-oriented NoSQL databases. Apache HBase [32] is one of the most popular columnar databases offering real-time access to very large tables with time-series support available via KairosDB [33]. In addition, Apache Cassandra [34] can be augmented with time-series operation. In fact, time-series databases, like InfluxDB [35], are yet another interesting storage technology.

E. Data analytics

Data analytics is driven by cognitive technologies, which are able to perform tasks that formerly only humans used to be able to do. Typically, the field of data analytics is divided into three different categories: a) descriptive analytics describing what the data looks like, b) predictive analytics predicting what is going to happen, and c) prescriptive analytics describing what should happen to reach the goal [36].

Some of the cognitive technologies that are increasingly adopted and can be deployed in predictive and prescriptive analytics are shortly described below:

- **Machine learning** refers to compute systems' ability to learn without being explicitly programmed. Machine learning explores the development of algorithms that can learn from and make predictions on data. Machine learning algorithms are often categorized as being *supervised* or *unsupervised*. Supervised algorithms can apply what has been learned in the past to new data, e.g., parametric/non-parametric algorithms, support vector machines, kernels, neural networks. Unsupervised algorithms can draw inferences from datasets, e.g., clustering, dimensionality reduction, recommender systems and deep learning [37].
- **Computer vision** refers to the ability of computers to identify objects, scenes and activities in images. Computer vision includes methods for acquiring, processing, analyzing and understanding digital images. Certain techniques, for example, allow for detecting the edges and textures of objects in an image [38]. The application of computer vision includes for example robotics, remote sensing and process control.
- **Robotics** refers to the interdisciplinary engineering and science that involves the design, manufacture and operations of robots, as well as software for their control and data processing. Recent advances in artificial intelligence, communications and sensors have produced more intelligent, capable and sensing robots. In practice, these developments enable robots to replace human labor in manufacturing task, as well as in a growing number of service jobs, such as maintenance [39]. For example, recent research [40] shows that robotics and automation of manufacturing processes translates into optimizing processes in the material and energy consumptions, which are important targets of the circular economy.

IV. TOOL RENTAL SERVICE

In this section, we describe how the previously presented digital technologies, namely sensors, networking, cloud-based platforms, data integration and data analytics, can be applied to a tool rental service to promote the circular economy. We present a rapid experiment of the tool rental service and develop a scenario anticipating the possible future of the tool rental service. Our aim is to afford understanding on the possibilities of digital technologies enabling more sustainable and circular business models.

A. Approach

Our AARRE project (Capitalising on Invisible Value - User-driven Business Models in the Emerging Circular Economy) explored user-driven circular business models and collaborated with multiple Finnish companies, Finnish organizations and Finnish decision makers in the circular economy field. The idea of a tool rental service is to offer an alternative for purchasing of tools, such as electric tools and cleaning equipment, which are used infrequently in urban economy. This kind of sharing economy can be an ecological option in certain conditions and on the other hand facilitates the storage problem of goods in urban housing [41].

The planning and rapid experimenting of the tool rental scenario is based on several discussions with eight AARRE project researchers, one start-up entrepreneur and various companies. The goal of our empirical study is to provide input for the discussion on how to disrupt current prevailing linear business models by employing digital data and IoT technologies.

B. Current deployment of the tool rental service

Our AARRE project conducted a rapid experimental tool rental service called Liiteri [42] in collaboration with Finnish IT-startup CoReorient [43] and hardware store K-Rauta. The other co-operation partners were Helsinki Region Environmental Services Authority HSY, Technology Industries of Finland, SER-kierrätys, City of Espoo, Purjebägit Oy, Kierrätysverkko Oy, Metrosuutarit.fi, Pyörähuoltoovelle.fi and Kauppahalli24.fi.

Liiteri is an online platform, where consumers can rent electric tools and house cleaning equipment. By registering as a Liiteri user, the consumer can choose the desired product and renting date via online platform. In addition, the payment is made via the online service at the same time. When the payment has been processed, the consumer gets an access code to the 24/7 Liiteri self-service point, which is an intelligent container in the city centre of Helsinki. The consumers can pick up the rented gear any time from the Liiteri self-service point, where there are good public transport connections. Alternatively, the consumer can choose a crowdsourced PiggyBaggy home delivery service [44]. An initial experiment to examine the utility of the Liiteri tool rental service was conducted and reported in another study [41].

C. IoT-enabled scenario for the tool rental service

In this section, we present an IoT platform based future scenario for the Liiteri tool rental service by employing

digital data and IoT technologies. Figure 1 presents the developed scenario, which aims to provide understanding of the anticipated possibilities of sensors, networking, cloud-based platforms, data integration and data analytics.

A beacon is a node aware of its location (e.g., equipped with Bluetooth) [45] and it can send signals to smartphones or other mobile devices. For example, the consumer’s smartphone can interact with beacons placed in the Liiteri self-service point via a Liiteri mobile application (later referred to as the Liiteri app). Bluetooth-based *beacons can be used for mobile door opening* when entering the 24/7 Liiteri self-service point [46]. Furthermore, the beacons can enable consumers to be recognized when entering the 24/7 Liiteri self-service point and *help them easily to find the selected tool or other rented gear with nearby notifications feature*. A payment for the selected product can be discharged using a *beacon-based mobile payment* or a more conventional online payment service provided by the Liiteri app.

The rental profile including demographic data and browsing history from the Liiteri app can be stored in the cloud-based Liiteri database and analysed for *personalized recommendations*. The Liiteri app can also allow the consumers to *access product information and reviews* to help them make their decision. At home, the consumers can be provided with a *guided usage service* by scanning the tool (equipped with beacon) with their phone. The Liiteri app makes it easier for the consumers to get useful information and even a guided replacement service in case of a broken part can be possible.

Sensors can measure for example acceleration, temperature, vibration and humidity of tools or parts of the

tools. *The sensor data can be exploited in business intelligence* in many ways, such as in *condition-based maintenance (CBM)*. CBM is a maintenance procedure based on the information collected through conditions monitoring and can be used for *diagnostics* and *prognostics* [47]. Prognostics based maintenance is often called as predictive maintenance. CBM of the tools can employ multiple sensor data fusion and analytics platform (either on-premise or cloud-based) to assess current failures (diagnostics) and possible future failures (prognostics). In our Liiteri scenario, the tools can be equipped with budget sensors connected to the cloud-based analytics platform. The sensor data can be stored in the Liiteri database and further analysed in batches with different data analytics techniques, such as machine learning, for diagnostics and prognostics purposes. The sensor data, especially concerning usage and failures, can be utilized in refurbishment activities and turn refurbishment into a potential and accessible option. The *predictive maintenance service* can ‘maintain the tools before they break’ in order to increase the lifetime of tools, and improve safety and usage experience of the tool rental service. A trivial consequence from refurbishment and increasing the lifetime of tools is decreasing the use of natural resources and waste.

A prognostics model employing machine learning can be developed for calculating a Remaining Useful Lifetime (RUL) and considering sustainability aspects in decision-making, i.e., deciding when maintenance is economically viable, environmentally bearable and equitable compared to reuse, remanufacture or recycle [48]. The tool usage data collected with sensors and the consumer feedback can be analysed to *improve future product design and performance*.

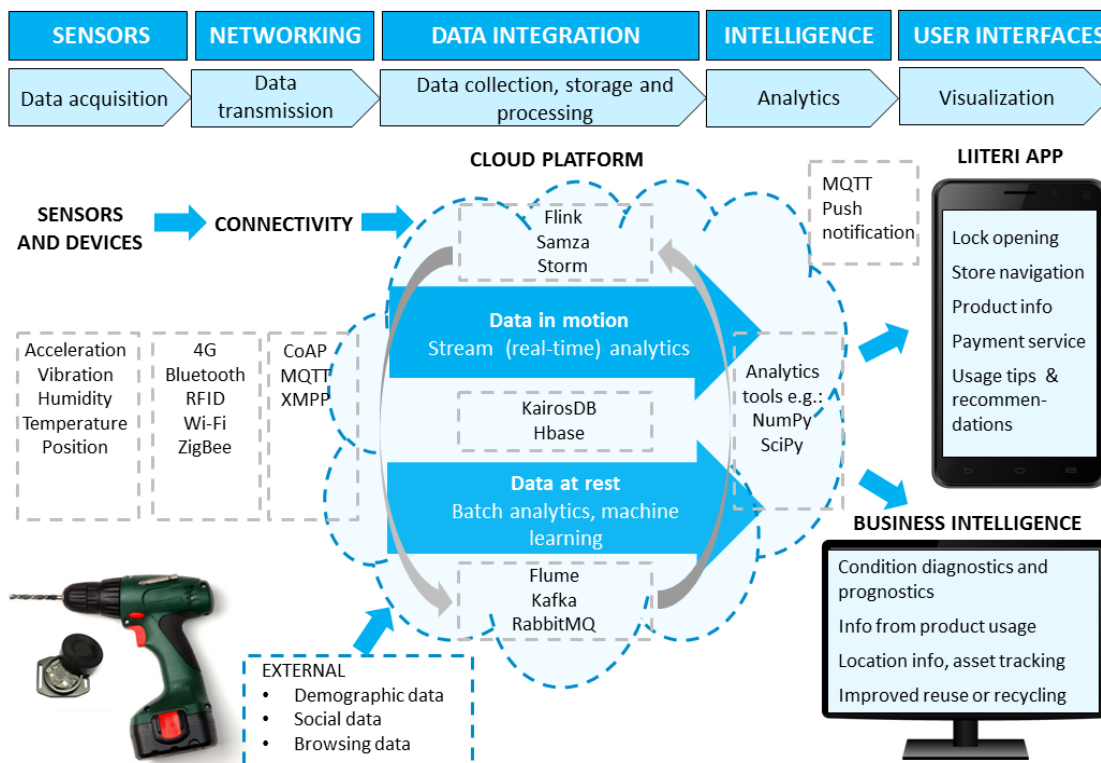


Figure 1. The IoT-enabled tool rental service business scenario.

In addition, the collected data can be analysed *to specify the recycling or disassembly* activities in order to maintain both economic and environmental value of the parts as high as possible.

The cloud-based Liiteri platform can also collect data about *the location of the tool and provide a connection with next user*. This promotes collaboration among consumers and facilitates crowdsourced delivery from user to user. During the delivery process, communication can be handled via the Liiteri app. *The deliverer can earn points*, which she or he can spend for the tool rental or redeem for cash. Home delivery service of the tools, in turn, can utilize the *real-time navigation information and the customer's location information for route planning and optimization of delivery routes* to reduce driving time, fuel consumption and exhaust gases.

V. CONCLUSIONS

IoT technologies and digitalization in general enable novel business models based on the circular economy. As a result, they offer a great potential to disrupt current prevailing linear business models [49]. This study contributes to the discussion on circular economy by providing a future IoT-enabled scenario for future development paths. The tool rental service scenario uses sensors, networking, cloud computing and data analysis technologies for selling services instead of goods, for designing products for regeneration and for creating added value through services. Generally, offering services instead of selling goods reduces the environmental footprint of product manufacturing and the private ownership of goods. At its best, this study awakes discussion among companies on how to create circular economy business by employing digital data and IoT technologies.

The scenario planning of this study has been qualitative and it includes researchers' own subjective interpretation. The previous study [41] examined the utility of the Liiteri tool rental service and the results indicated that renting could be an attractive choice to consumers if crucial consumer expectations are identified and met. This attitudinal change is partly attributable to technological improvements, such as widespread digital cloud platforms, which make sharing of goods easier. On the other hand, especially young people prefer services to ownership of goods.

In order to proceed towards commercial utilization of the presented concept, further work on the IoT-enabled tool rental service scenario includes addressing multiple technical, usability, and profitability aspects, in addition to the environmental viewpoint. The main technological challenges include the overall cost-efficient logistics on large scale, data security, interoperability of IoT sub-systems, and interface with the consumers. The usability of the service must meet or exceed the level of current modern competing e-commerce platforms. Overall, the business challenges are the same as for e-commerce services in general. To be commercially viable, the service must maximize the user satisfaction and minimize the costs through intelligent use of IoT technologies. Future work needs to evaluate which parts of the system are efficient as automated, and which parts

should be managed by human operators, resulting in an optimal profitability. Full examination is needed on the types of products that provide most benefit from the circular economy service concept in terms of environmental benefit. Moreover, next steps of future research endeavours could focus on implementation of a next generation IoT-enabled circular economy service for a larger group of people, with the systematic collection of consumer experiences for further service improvement.

Despite the various remaining challenges, there is a growing amount of consumers that see the environmental friendliness as an added value factor. This could facilitate the accumulation of consumers in the early phases of development, towards ultimately better collaboration between the human use of technology and the environment.

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