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Blockchains as a Path to a Network of Systems

An Emerging New Trend of the Digital Platforms in Industry and Society

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Abstract

At the beginning of the 1990s, the Internet's various fragmented information networks were combined into one integrated network of systems. As a result, the commercial utilization of the Internet boomed, creating completely new business models and economic structures in the process. A similar reaction is now anticipated from the digitalization of industry and society at large. However, the main question is: "How can all the separately structured, isolated systems be fused into one seamless network of systems?"

So far, the problem has mainly been addressed from the standpoint of centralized and decentralized system architectures. Our analysis shows, however, that completely new and innovative technological approaches, such as the blockchain technology, are emerging to address this problem. These new distributed architecture solutions may completely revolutionize the anticipated structures and business models of the digitalization currently in progress, as they allow machines to autonomously share much more than just data, e.g. computing power, storage capacity or even electric power. As a result, understanding digitalization in its full capacity requires a systems approach and a new kind of higher-level thinking on the scale of a network of systems.

Key words: Digitalization, industrial Internet, platforms, blockchain

JEL: L14, L15, L86, L96, O33

Laitteet pilveen – vai pilvi laitteisiin?
Keskustelunavauksia teollisuuden ja yhteiskunnan digialustojen uusista kehitystrendeistä

Tiivistelmä

Kun internetin hajanaiset tietoverkot 1990-luvun alussa yhdistettiin yhtenäiseksi järjestelmien verkostoksi, internetin kaupallinen hyödyntäminen räjähti, synnyttäen täysin uudenlaisia liiketoimintamalleja ja talouden rakenteita. Vastaavaa murrosta ennakoidaan nyt teollisuuden ja yhteiskunnan digitalisaation saralla. Kysymys kuitenkin kuuluu, miten toisistaan erillään rakentuneet järjestelmät saadaan yhdistettyä saumattomasti toimivaksi järjestelmien verkostoksi?

Toistaiseksi ongelmaa on ratkottu pitkälti keskitettyjen ja hajautettujen järjestelmäarkkitehtuurien pohjalta. Analyysimme kuitenkin osoittaa, että syntymässä on täysin uusiin teknologisiin ratkaisuihin, kuten lohkoketjuteknologiaan, perustuvia innovatiivisia arkkitehtuuriratkaisuja, jotka saattavat täysin mullistaa digitalisaation ennakoidut rakenteet ja ansaintalogiikat. Uusien vertaisverkkoarkkitehtuurien myötä digitalisaation ymmärtäminen vaatii systeemitasoisempaa ajattelua, sillä niiden avulla laitteiden välillä voidaan autonomisesti jakaa muutakin kuin pelkkää dataa – esimerkiksi laskentatehoa, tallennustilaa tai energiaa.

Asiasanat: Digitalisaatio, teollinen internet, alustat, lohkoketjuteknologia

JEL: L14, L15, L86, L96, O33

1 Digital compatibility promotes commercial utilization

To some extent, the current state of digitalization both in industry and in society at large resembles the evolution of the Internet, which was triggered off when a range of fragmented information networks using different communication technologies were combined through a single language, the TCP/IP protocol. However, large-scale commercial utilization of this network was complicated and a more widespread business interest in the Internet did not arise until the first general-purpose adaptable system platform, the *World Wide Web (WWW)*, was introduced.

In many ways, one of the key problems of digitalization in industry and society is very much the same in this respect. While the existing systems can be interconnected with ease, an equivalent 'counterpart' to the WWW still remains to be developed for the network of smart devices and services. To enable all the different information systems and architectures to understand one another flexibly without a hitch, some kind of a shared system platform needs to be created for them. Without such a platform, not only it will be extremely difficult to develop networks of smart devices and services, their commercial utilization will also remain highly uncertain. Consequently, it is imperative to be able to combine the individual component systems into a coherent and reliable network of systems before full-scale commercial utilization is conceivable. At the same time, the importance of various standards in ensuring interoperability, compatibility, and functionality between systems and networks is highlighted.

2 Digitalization involves more than just data

The digital transformation of industry and society is reaching a level that can be compared to the industrial revolution propelled by steam and electric power[1]. The all-encompassing transition to digital technology can be perceived as a threat, but also as an opportunity to society, industry, other actors and ultimately individuals in terms of employment (Frey & Osborne, 2013; Pajarinen & Rouvinen, 2014; Juhanko, Jurvansuu, Alhqvist et al., 2015; Ailisto, Mäntylä, Seppälä et al., 2015).

A major trend in the current digital transformation of industry and society is the integration of the existing embedded systems with new Internet-based standards, platforms, systems, devices and services. This convergence permits the emergence and utilization of new types of device and service platforms, both locally by the device itself as well as remotely via cloud-based services (Porter & Happelman, 2014; Pon, Seppälä & Kenney, 2014; 2015). At the same time, these new intelligent social and industrial product and service platforms will make use of open data as well as third-party innovations, complementarities and other platforms (Seppälä & Kenney, 2012). It is also worth noting that the importance of various service software, data and advanced analysis to the creation of real-time customer value and the provision of new services will increase (Juhanko, Jurvansuu, Alhqvist et al., 2015; Ailisto, Mäntylä, Seppälä, 2015).

1 The idea of digitalization as we understand it today dates back to the United States of the 1950s when the authorities began planning a new communications system that would be unaffected even by a nuclear strike. Commercially, digitalization did not get off the ground until major steps were taken to digitize telephone exchanges and networks and the first Internet operators emerged in the 1980s. Industry did not catch up until about a decade later. A little before the turn of the millennium, the idea of an Internet of things was suggested where physical objects could communicate over the Internet by means of various wireless identification technologies.

In this paper, we examine one of the numerous potential platforms for industrial and social digitalization. We analyse and describe the impacts of the peer network-based blockchain technology and its suitability as a part of a network consisting of smart products and services (including even autonomous systems).[2]

From the point of view of social and industrial digitalization, the blockchain technology is an interesting subject of analysis for a number of reasons. First, venture capital investments in the blockchain technology ecosystem have greatly increased over the past few years, reflecting a trend similar to the investments made in the WWW in its early days.[3] Second, said technology has proved itself in that it has been quickly adopted across the world and due account of its potential has been taken in the innovation projects launched by major technology companies. Third, as far as platforms go, the blockchain technology offers a number of promising, even unique technical features.

Case: IBM & Samsung – Adept
In September 2014, IBM announced that it will join forces with Samsung to develop a platform for smart devices and services called 'Adept'. It was to combine the best features of three communications protocols to provide a coherent functional system. It will be based on the blockchain technology where the communications delay is tweaked with the Telehash protocol. Safe data storage and efficient distribution are to be ensured by the proven BitTorrent technology.

IBM's researchers estimate that Adept may reduce the maintenance costs of the system architecture of a smart products and services network by up to 99%. Thanks to the blockchain technology, no server centres are required. Instead, the entire platform can be generated locally and autonomously through the collaboration of smart components. Adept is to be distributed as an open source code system freely available to all users (Ahluwalia, 2014).

Our analysis shows that a range of systemic, autonomous, flexible and scalable digital service layers based on completely new technological solutions are emerging to complement the existing industrial system architectures. Aside from the fact that these new technologies are able to offer data-related customised applications, software tools and additional features in response to customer needs, they are adaptable to a range of dynamic-static production solutions in terms of other production factors as well, even concurrently at the same time as a product or

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2 In brief, blockchain technology is a method by which parties previously unknown to one another can jointly generate and maintain practically any database on a fully distributed basis. In reality, the system works so that each party is distributed a copy of the database (or part of it) and all of them may also make changes to the database subject to certain predefined rules. The changes made by the various parties are assembled and stored in the database at regular intervals as bundled packets called blocks. When new blocks are added to the original database, they form a blockchain, or an up-to-date database containing all the changes made.

3 Publicized venture capital investments in peer-to-peer network and blockchain technologies, particularly the cryptocurrency ecosystem, have grown rapidly since 2012 when a total of USD 2 million was invested in this ecosystem. Subsequently, the investments in cryptocurrencies reached around USD 100 million in 2013 and USD 350 million in 2014, whereas by the end of July 2015 new venture capital investments had already amounted to around USD 400 million. Extrapolated over the rest of the year, it would mean that the total of venture capital investments in cryptocurrencies will amount to approximately USD 1.2 billion by the end of 2015. If realised, this amount would be roughly equivalent to the nominal value of all the investments in the Internet ecosystem in 1995 – in other words, just a couple of years after the introduction of the *WWW*, whereas in 1993 investments in this ecosystem were still practically non-existent. In this respect, the trends of investments in these two ecosystem are very similar. (Zook, 2002 and <http://www.coindesk.com/bitcoin-venture-capital/> & <https://www.quandl.com/MONEYTREE/INVEST_INTERNET_QUARTERLY>).

service is being used. However, reconciling the numerous system architectures may pose problems in the short term unless prompt action is taken to agree on industrial standards akin to TCP/IP and WWW offering an adequate standard of data security and reliability.[4]

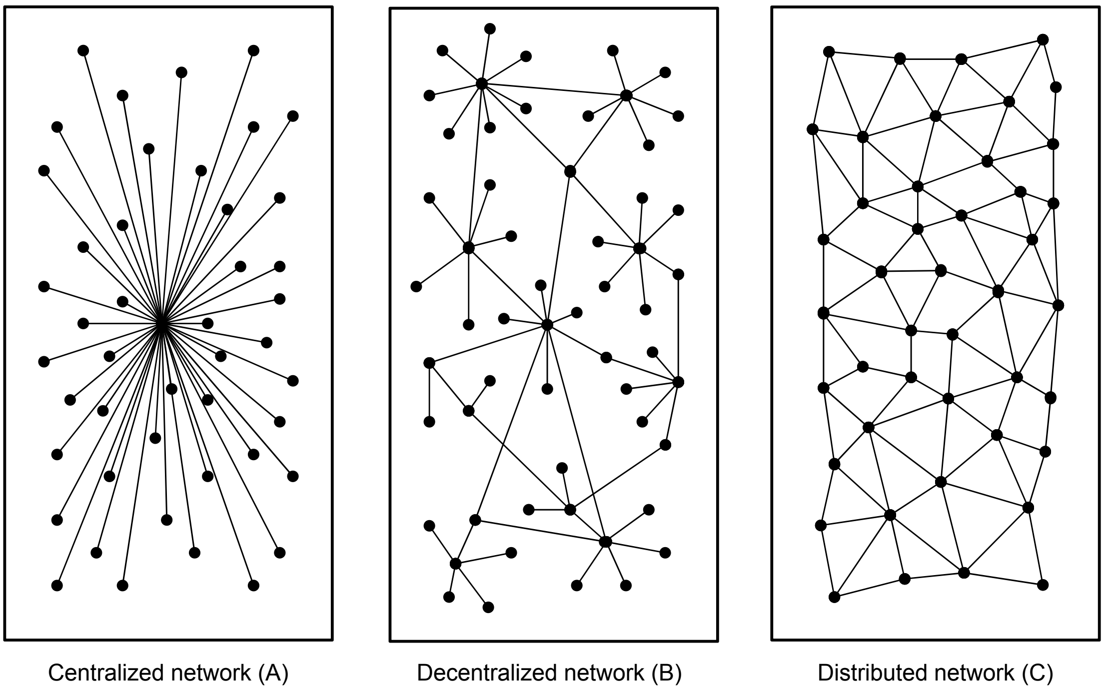
The following section will examine the problems associated with the existing architecture and the blockchain technology and its recent development where the current trend is away from 'cloud-linked' towards 'cloud-forming' components. The fourth section will ask how to use the recent technological trends to expand our perception of digitalization in industry and society, and assess these new structures, their limits and future. As the world is changing, we need to ask ourselves: Are we willing to change our way of thinking?

3 From cloud-linked components to cloud-forming components

3.1 Problems of the existing architecture

So far, the plans for the implementation of a network of smart products and services have primarily been based on centralized (see Fig. 1A) or decentralized (see Fig. 1B) cloud services. With these types of solutions, smart components share information over the Internet via a cloud service provided by the device manufacturer, for example. While this approach is ideal for a wide range of purposes, this is not always the case. Problems arise when we deal with smart products and services that are low in price but have a long lifecycle (see Fig. 2).

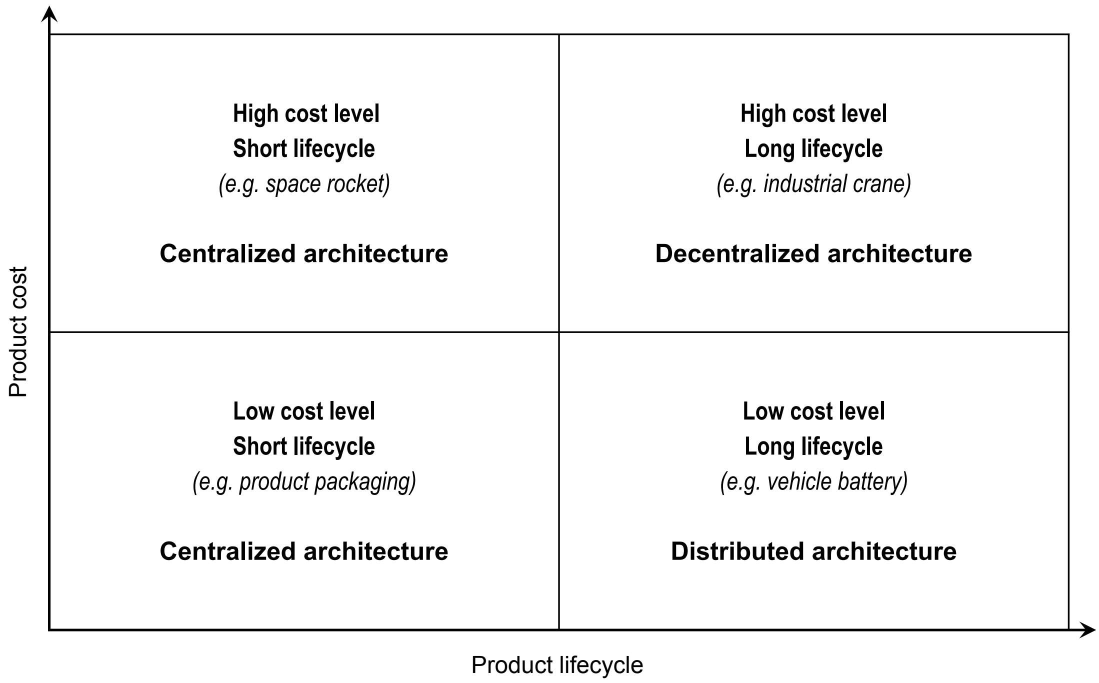
Figure 1 Degree of connectivity of networks



Sources: Baran (1964), Mougayar (2014).

4 See Annex 1 for a comparison of the features of the Internet and the smart products and services network.

Figure 2 Suitability of network architectures for various production contexts



Source: Ahluwalia (2014).

Often, centralized server solutions and decentralized cloud architectures are far too complicated for many purposes; this makes it necessary to maintain a huge background process even if the volume of device-to-device communications were relatively low. In reality, cloud services need to be financed either by charging higher rates to customers or by capitalizing on the data generated by the system, for example by anticipating production line disruptions or selling customer profiles to advertisers, insurance companies or other third parties.

However, such capitalization may not necessarily be economically viable in the long term, particularly in industry where the potential offered by targeted advertising is far more limited than in the consumer business. It is likely that estimated revenues from such data analytics have been overly optimistic in many forecasts. In an intensely competitive market, the value of data generated as a by-product of operations tends to fall quickly, and, even in the absence of competition, it may be more attractive to customers to collect the necessary data themselves using their own sensors, if the price of the data is held artificially high (Ahluwalia, 2014).

Also, it is realistic to assume that many smart products and services will remain in service longer than the service providers maintaining them will remain in business. As mentioned above, the biggest challenge in this respect is posed by products and services with a long life cycle but a low production cost. With them, the cost of maintaining a centralized or decentralized architecture will over time be disproportionately high relative to the price of the products and services involved as the number of devices grows. Consequently, there are no guarantees that cloud architecture will prove functional or profitable in the long term.

3.2 Short introduction to the blockchain technology

In brief, the blockchain technology is a method by which parties previously unknown to one another can jointly generate and maintain practically any database on a fully distributed basis. In reality, the system works so that each party is distributed a copy of the database (or part of it) who may then make changes to the database subject to collectively accepted rules. The changes made by the various parties are assembled and stored in the database at regular intervals as bundled packets called 'blocks'. When new blocks are added to the original database, they form a blockchain, or an up-to-date database containing all the changes made.

To ensure that the other network users accept the proposed block as part of the shared blockchain, the proposing party must sign their block using a solution to a highly complicated mathematical problem specific to each individual block. The blocks are 'stacked' in such a way that any tampering with the data will change the problems to be solved within the blocks. When the questions change, the solutions found to the preceding blocks no longer apply and the other nodes of the network reject the proposed fradulent blockchain. During the time it takes for a fraudster to solve new problems, the rest of the network proceeds much further.

In other words, the method is based on a never-ending race between the individual versions of the database in which the winner is the version that has made the most progress. The reliability of the method stems from the fact that working with the various versions calls for constant computational work. As long as more than half of the computing power of the network supports the 'honest' version of the database, even a large number of attackers cannot shake the distributed unanimity and consensus of the network as to the unadulterated contents of the original database.

So, in essence, a blockchain is a distributed digital sandglass where mathematical problems are the trickle. It allows for the creation of a jointly generated electronic time stamp that all participants can trust, even if they do not trust one another. In this manner, as it is easy to verify the origin and accuracy of the information whatever its source, no external intermediary (such as a central server) trusted by all the parties is required to validate the data.

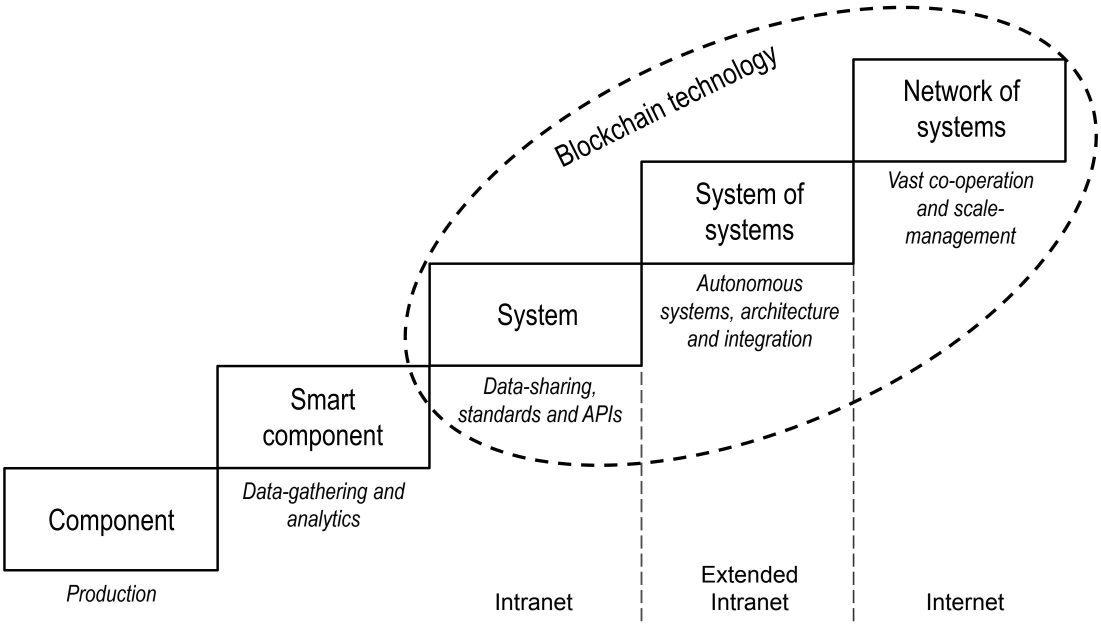
Consequently, the blockchain technology is extremely reliable as a distributed method of data storage. In a sense, it is more universal in its reliability than earlier methods. With the blockchain technology, unlike previous solutions, it is not necessary to trust any single member of the network because the accuracy of the data can always be cryptographically verified irrespective of the source. The only prerequisite for reliability is that at least half of the nodes of the network – measured in terms of computing power – are honest. Accordingly, part of the data can be safely entrusted even to parties who would clearly stand to gain from tampering with the information.

3.3 Evolution of the blockchain technology

The first application to make use of the blockchain technology was the Bitcoin cryptocurrency[5] introduced in 2009 without fanfare. Already in 2013, it was reported that the Bitcoin peer network was by far the fastest cloud in the world with a computing power 250 times higher than that of all the world's 500 most powerful supercomputers put together (Cohen, 2013). Since then, the evolution of the blockchain technology has proceeded from the more readily digitizable products and services towards more complicated universally applicable architecture solutions, systems of systems and a network of systems (see Fig. 3).

As it is, the blockchain technology looks like a promising candidate for a platform for providing smart products and services especially in situations where other architecture solutions prove to be too cost-intensive relative to the total production costs. With blockchain technology, the network of smart products and services can be implemented as a fully autonomous peer-to-peer network between the actual devices (see Fig. 1C), without any need for a background architecture based on external cloud services.

Figure 3 Levels of the industrial Internet system architecture. The blockchain technology may provide the missing piece of the puzzle combining the three highest levels of the staircase



Sources: Adapted from Juhanko, Jurvansuu, Alhqvist et al. (2015); Ailisto, Mäntylä, Seppälä et al. (2015).

5 Bitcoin is a payment platform application where the network users create a distributed ledger to record account balances and payment transactions using the blockchain technology. No bank, credit card company or other central authority is necessary for the system to operate; instead, the users create the entire service between themselves on a distributed basis. The Bitcoin network has been operating more or less faultlessly since 2009 and currently transmits electronic payments to a value of tens of millions of euros on a daily basis. <https://blockchain.info/charts/estimated-transaction-volume-usd>

4 Are we asking the right questions? Are we willing to change our way of thinking?

Currently, the prevailing trend in information society is that computing power and data storage capacity are being transferred to the cloud. Many organisations are agonising over whether to store the data on the company's own servers or in the cloud and who should own the data not residing on in-house devices in a given situation (Ailisto, Mäntylä, Seppälä et al., 2015 pp. 16–17; Manner, 2015). What should be understood, however, is that if the network of smart products and services is built on a peer-to-peer architecture based specifically on the blockchain technology, these questions are misguided to begin with. When each smart component itself is an equal part of a peer network, the division between the device and the cloud loses all relevance.

Furthermore, recent innovations in data encryption have made it possible to allow for untrusted parties to transfer, store and even task any sensitive data without compromising its privacy. *Enigma*, for example, utilizes encryption algorithms, peer-to-peer networking and blockchain technology, to allow for untrusting parties to jointly store and run computations on each other's data while keeping the content of the data completely private.[6]

Therefore, the new and more relevant key question in the convergence of the device and the cloud is: *how adaptable are the microcircuits of the smart components to various unplanned ad hoc tasks*. When it is the components themselves that make up the cloud, flexibility and benefits will grow in proportion to the microcircuits' ability to temporarily execute the tasks normally performed by other circuits. If the level of flexibility is high enough and the network large enough, a peer-to-peer network of smart components will be autonomously able to perform exactly the same duties as decentralized cloud services – but at a fraction of the cost.

Consequently, the blockchain technology may revolutionise the anticipated value-creation logic of social and industrial digitalization precisely because by using this technology, smart components will be able to share much more than just mere data – computing power, storage capacity, bandwidth or even energy, for that matter. After all, with the aid of blockchain databases, smart components are capable of independently creating completely reliable and fully distributed exchanges and marketplaces. As a result, exchange and cooperation will become possible even between smart components that do not trust one another and that were not originally intended to engage in any mutual exchange. This would permit flexibility and cost optimization in production on an unprecedented scale.

To harness the production efficiencies offered by the blockchain technology, it is indispensable that the data as well as other production factors, such as computing power, storage capacity and energy, are truly shared by all the smart components and thus accessible to all operators. As ownership-related aspects become blurred and so partly irrelevant, a value-creation logic based on an exclusive control of the production factors ceases to work.

In principle, a company may well seek to protect the production factors in its ecosystem by having its smart components simply refuse to communicate with competitors' ecosystems and

6 See Zyskind, G., Nathan, O. & Pentland, A. (2015).

Case: Smart batteries and autonomous marketplaces

For a long time, the popularity of electric cars suffered from the long recharging time relative to the distance they are able to travel on a single charge. In 2013, Tesla solved this problem by introducing a service concept for electric cars, in which the battery pack is replaced by a fully charged battery at the service station instead of being recharged. If the Tesla concept is adopted more widely and the batteries are provided with adaptable microcircuits, the concept can be developed much further using the blockchain technology, for example as follows:

When the battery is left at a service station to be recharged, it connects to a peer network autonomously created by the smart components involved. Next, the battery starts gathering data on the supply and demand of electricity, battery stock levels at the nearest recharging stations, road traffic volumes, the status of each battery within the then-current operating range, and a wide range of other things. Having collected all this information, the battery performs a trend analysis to determine whether it would make sense to buy electricity at the local station and recharge itself right away or whether it would be more profitable for the battery to sell the power it still retains to some other party and wait for the market price of electricity to fall.

To carry out the trend analysis, the battery may, if necessary, buy additional computing power from other devices, such as batteries waiting to be recharged, the station drinks vending machine, a robot vacuum cleaner, that do not need their built-in processors for other tasks at that moment. The battery will look up the supplier offering computing power at the lowest rate in the exchange jointly created by the smart components with the help of the blockchain technology. Compensation for the computing power will be paid by the battery from its device-specific account to the accounts of the other devices using a cryptocurrency based on the blockchain technology.

Once fully recharged, the battery will reconnect to the marketplace generated by the components and start marketing itself to other vehicles in the vicinity with compatible batteries with a low charge level. Moreover, the battery can offer itself to vehicles with a high battery charge level recharged at a higher cost. If the driver accepts the offer, the more expensive battery will be left at the station, the difference between the battery and the vehicle settled in cryptocurrency and the vehicle will continue its journey with cheaper electricity. In extreme cases, the battery may offer itself at a loss if there is a risk of getting stuck at a remote station with little traffic. Another possibility is that the battery can offer itself for use in other assemblies as well, such as welding machines or in households, provided that the components are mutually compatible.

Once the battery has accumulated enough profits on its device-specific account, it will order servicing for itself and pay for it from its account in cryptocurrency. If any surplus profit is left after all the operating costs have been paid off, the battery will credit the difference to the company that owns it. In between the payments, the owners will not need to pay any special attention to the battery because it transacts business fully autonomously as if it were a subsidiary consisting of a single component. As a result, there would be no need for any costly centralised cloud services or other background processes designed for millions or even billions of batteries. Instead, each battery would buy the products and services it needs from the most affordable supplier autonomously at any given time.

At the end of its service life, the battery puts its recycling out to open tender and pays for it from its earnings, ensuring that the customer or company incurs no expenditure for waste management. As its final action, the battery will credit any 'inheritance' left to the company that owns it.

build a closed network of their own. However, in a competitive environment based on the blockchain technology, such a segregated business model would pose a serious risk to the company's competiveness and continuity. With the competitors adopting more innovative value-creation logics based on open inter-system cooperation and reaping efficiency benefits, a company that isolates itself runs a fatal risk of extinction.

4.1 Implications for business management

If all the actors in society were to join the network of smart devices and services, it would be easy to predict that services would account for a far greater share of added value generated in industry than today. An architecture based on the blockchain technology would blur this boundary between industry and services even further. While attention will inevitably focus on the development of services, it is important to understand that infrastructures, the device stock and manufacturing will continue to play a significant role (Seppälä & Kenney, 2012; Seppälä & Kalm, 2013). The marketing of industrial services cannot commence until the system of industrial products and related devices and infrastructure have been successfully marketed to the world. Therefore, the importance of developing comprehensive systems, smart products and services by all the actors involved should not be overlooked in industrial strategies.

When the strategies for industrial digitalization are drawn up, it should be borne in mind that the lifecycle of telecommunications technologies is usually very long. With computers, it took over 20 years before the Internet reached the peak of its development and with mobile devices this moment still lies ahead.

Now is the right time to launch the first architectural pilot system and software implementation that make use of the peer-to-peer and blockchain technology, and possibly other similar disruptive technologies. Accordingly, companies are well advised to set aside funds for the construction of proprietary pilot platforms and introduce the first products to the market over the next 3–5 years. This will give enough time to renew the entire product and service portfolio before the anticipated technology peak is reached.

At the same time, companies should actively seek to acquire expertise in innovations like the blockchain technology and in this field in general. In practice, this could be accomplished by launching R&D pilot projects in collaboration with universities. It would also be advisable to consider venture capital investments in start-up companies working with the blockchain technology.

In the efforts to develop business models, the blockchain and other similar technologies should, above all, be perceived as an excellent opportunity to access completely new markets and earning logics. After all, one of the biggest challenges facing the Big Data business is that the masses of data often come in highly diverse formats, and so refining the exhaust data to create value is often extremely complicated (Hurberty, 2015). In a system architecture based on the blockchain technology, all the data to be shared are generated in a fully predictable format and freely available, and will also be retained in the blockchain completely. Offhand, it is hard to imagine a better starting point for creating value out of data.

So far, most, if not all companies have abstained from opening their sensor data to free access on the grounds that some of their sensor data might be sensitive and needs to be kept private. It should, however, be understood that the need for data privacy no longer restricts companies in this respect and therefore it no longer is a valid decisive factor for strategy. Due to some recent developments in cryptology and the blockchain technology, companies can allow for external parties to perform analyses on their sensor data in any chosen capacity without actually revealing the content of the data – or even the results, if so desired – to any external party. Companies should be aware of such developments and understand that utilizing these innovations can lead to *enhanced* data privacy and cyber-security, and a better competitive edge, compared to just simply keeping all sensor data offline.[7]

4.2 Implications for the public sector and politics

Similarly, the public sector should be prepared for the maturation of the blockchain technology over the next few years. Because of its properties, it should be understood as one of the potential tools for driving structural changes. For example, it could reduce regulation in certain sectors of society through intelligent societal design enabled by Big Data.

Thanks to its reliability, the blockchain technology could also greatly improve the response of the public administration to the policies adopted by the Government, which would ease the cost burden in the public sector. Furthermore, this technology is ideal for creating anonymous yet public databases, making it possible, among other things, to hold fully transparent electronic ballots without compromising the voters' anonymity.[8]

Naturally, standards will play a key role in the digitalization of industry. However, the European practices related to platform development diverge greatly from the policies adopted in North America. Where the United States and Canada usually rely on the market forces to create standards, Europe tends to prefer state intervention in the standardization efforts. While there is probably no one answer as to which approach should be adopted here, it is nevertheless important for the public sector to at least be aware of the need for the preparation of standards for peer-to-peer and other such technologies necessary for industrial digitalization.

From the point of view of research and research funding, it is essential to grasp the full potential of industrial digitalization and the vital importance of the creation of a shared platform with the ability to harness the commercial benefits. Peer-to-peer network technologies, like the blockchain technology, should be perceived as disruptive innovations for which a special research programme should be drawn up where possible.

7 To provide a practical example, the anti-secrecy organization Wikileaks has occasionally stored its whistle-blowing documents – that is, some of the most sensitive information in the world – by locking them with a strong encryption key and distributing them globally in peer-to-peer filesharing networks to anyone willing to download them for safe-keeping. <http://on.rt.com/2ujdgs>; <http://www.businessinsider.com/wikileaks-insurance-file-2013-8?IR=T>

8 For instance, the Liberal Alliance of Denmark has adopted a voting system based on the blockchain technology in its internal party ballots. (Sparkes 2014; see also <www.bitcongress.org>)

5 Digital revolution calls for a systems approach

Only a couple of years ago, it was widely believed that Big Data will completely reshape industry and society. Subsequent developments have demonstrated, however, that a new industrial revolution will not be achieved simply by connecting devices and services to the Internet or just by reprocessing Big Data. At the same time, the public debate on industrial and social digitalization has been bogged down by excessively narrow thinking where the network of smart devices and services is seen merely as a network for the distribution of data.

Preferably, the network of smart devices and services should be perceived, through an approach based on systems theory, as a more extensive whole where data constitute just one of the shared resources among many other production factors. When the various components are able to efficiently share computing power, storage capacity, energy, etc., the total benefits to be gained in terms of production efficiency and productivity will be of a completely different order of magnitude compared to a situation where optimization efforts are based on data related to specific operations.

When the first WWW server went online in the early 1990s, hardly anyone could imagine how radically this innovation was to reshape society's economic operating environment over the next quarter of a century. The value-creation logics currently applied by the biggest players of the global economy could hardly have been envisioned at that time. It would be absurd to think that we would be any wiser in the face of the on-going digitalization.

The revolutionary character of industrial and social digitalization is not due to progressive innovations and further efforts to improve the efficiency of existing value-creation logics by means of Big Data. The true driver of change lies in disruptive innovations like the blockchain technology that enable completely new business models and unforeseen value-creation logics. The time has come to raise the debate on the digitalization of industry and society to a new systemic level.

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Annex 1: Comparison

Internet • Global data communications network.	**Network of smart products and services** • Network of inter-communicating things.
TCP/IP • Communications network enabling interconnection of various information networks and device-to-device communications in these networks.	**Blockchain technology** • Protocol enabling the creation of high-security public databases on a fully distributed basis.
World Wide Web • Architecture enabling anybody to freely create applications and make them available to the public using the TCP/IP protocol. • Enables the presentation of hypertext, images and other media content in web page format and later fully dynamic and interactive sites such as browser-based games, map services, online banking services, social media services, etc. • Enables anybody to publish practically any content without intermediaries.	**Adept, Ethereum, Maidsafe, etc.** • Architectures that allows anyone to create applications utilising the blockchain technology and to make them publicly available. • Enable digital currencies, smart contracts, micropayments, electronic asset registers, identity and reputation management registers, voting systems, inter-device payments, autonomous organisations, etc., all generated on a fully distributed basis. • Enable anybody to execute practically any interaction requiring mutual trust electronically without intermediaries.

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