eit Knowledge & Innovation Community

EIT ICT Labs

Digital Cities

White Paper

Magnus Boman

Executive Summary

The *status quo* of digital cities is analysed in detail, using six different perspectives:

1. Social interaction
2. Safety
3. Data management and analytics
4. Mobility
5. Consumer Lifestyle
6. Crowd-based services

A unified list of the most important trends, challenges, and opportunities that lie beyond state-of-the-art is, in brief:

TRENDS

- Public organisations provide open data for the creation of new services for smart cities. More data available via open APIs, both governments and companies are providing access. Exponential increase in data volume, velocity and complexity.
- Big data and open data enable digital service mash-ups together with crowd-based data. Social data is of ever-increasing interest to app developers, and so is feeding back information to (groups in) social networks.
- Linked data: towards the real world of heterogeneous networks, moving into a world where all data is linked. Software structures are constantly evolving towards component-based architectures that support dynamic high-level composition through wrapping and adaptors.
- An increasing number of citizens in digital cities are always on mobile networks; smart phones are increasingly powerful tools that can act as sensors, and provide information. The rise of social media platforms has shown that people want to create and share their content with others; in the future, this will be included in the *Internet of Things* as a part of social media. Personalised and customised physical and digital services will in the near future significantly extend and enrich the current mass market.
- Emergence of distributed sensing. Sensors are becoming more widespread in digital cities; feeding government databases with early signals and increasingly useful information on how to prevent threats. The amount of data sensed (and available for control) will grow exponentially, enabled by the Internet of Things.
- Knowledge of and access to patterns mined from mobility data becomes the main enabler of a multitude of new information-intensive services and applications. Mobility patterns and people mobility make

possible new ways of accurately measuring exposure to commercial and governmental messages in digital cities. Well-founded estimates of population densities can be made bottom-up using mobility patterns, increasing the probability of timely and adequate management of mass events and disasters. Services boosting safety in digital cities are moving from call services to multimedia services.

- Online communities, services, and shops have to fight for consumer attention, data, time, and money. Consumers want instant gratification: more information but with less depth. Online content generation is growing exponentially, as users actively contribute explicit data via online (social) services; data about items and services purchased, about themselves, and about their friends. Emergence of a new consumer type: the working consumer, contrary to the conventional role of passive kings to be waited upon. *Everyone as a service*.
- The advent of cloud computing and other large-scale distributed computing techniques let users outsource their computing needs to third parties, shifting the online world to a model of collaboration and continuous data creation, a world of Big Data.

CHALLENGES

- A key technological challenge is to manage to link openly available software components with smart devices and tangible artifacts. This requires open and standardised APIs. Frequency allocation issues and new multimedia service requirements, as well as coverage issues and related problems of communication, pose further questions. As the rates of data and meta-data increase, the allocation of network and configuration of network parameters becomes a problem for the network operator. Mobility data is typically hidden in other types of logs that are generated in extremely high volumes from separate, distributed sources. Such data must be stored in a scalable manner.
- Providing Europe with a legal framework for sensors and open data: future digital cities will be providing lots of data to, and will be collecting from, citizens. Before this data can be used for novel services, policies for exploitation have to be defined. Privacy and information security responsibility issues. Mobility information can be extracted from a combination of several more or less isolated systems managed by different stakeholders. The owner of user data may be prepared to disclose a certain aspect or aggregate of the data to another stakeholder. Doing this robustly and securely poses several crucial challenges for systems design and business model development. Current *Internet of Things* solutions are fragmented and target specific vertical domains and/or specific types of applications. Interoperability and standardisation efforts are required.
- Innovation ecosystems for the digital cities of the future have to be defined. Concrete steps include revenue stream identification,

public/private partnership brokering, countering the pains of ever-increasing urbanisation, and open data being made available to developers and user communities. Rural areas will need to develop services that make it convenient and possible for the remaining population to stay. Creating an open platform for component-based visual design of apps requires standardisation. For user-composed and personalised services to become ubiquitous, the challenge is to create an open platform based on recognised (*de facto*) standards.

- Countermeasures must be taken against future ‘digital loneliness’. The digital cities of the future must use data to create spaces that foster physical and real cooperation, co-creation, co-living, and interaction. This can potentially also support virtual communities (‘digital villages’). Social interaction and responsibility should, using the available data of connected artifacts, be employed to increase the participation of citizens at all levels in society. This would cover all social and societal issues, such as co-governance and future services.
- Citizen behaviour: reluctant citizens may not accept to participate in a sensing or surveillance activity, because of privacy issues; the right to privacy is not absolute and uniformly adhered to. Even in cases where legal privacy regulations are in place, it can still prove difficult for citizens to claim their rights in practice. Some citizens are not yet comfortable with using very sophisticated communications systems. Understanding data requires visualisation, interactivity, and credibility. Information overload: human capabilities for absorbing information have not increased with increased data flows.
- Data integration: presenting a unified view of all the enterprise data and systems. Data sources may be statistically skewed or biased with respect to each other, or for a particular application. Naïve crowdsourcing can lead to herd behaviour rather than collective intelligence. Coordination is often necessary, and critical mass must be attained.
- Scalable cost-efficient data analytics and management solutions that can support a mix of structured and unstructured data. Accelerating time to insight. The number of data sources increases, which makes it harder and in some cases infeasible to store every piece of data. Monetise on new types of data. Crowd-based services must be delineated, for example in a passive (Big Data) vs. active (user behaviour) dichotomy, to correctly identify business opportunities. Each new digital service requires adequate identification of future, not just current, user needs. Big data analytics, making sense of data in intelligent ways, is needed for value-added services.
- New ways of monitoring consumer lifestyle require an expensive investment into infrastructure. The fact that very few players can afford such investments, there is a risk of vendor lock-in.

OPPORTUNITIES

- New ways of sensing the environment are being made available, and may be employed, if accepted by citizens. Deploy ad-hoc networks to mitigate coverage issues. User-controlled privacy: the user may control the level, lowering the threshold for accepting new services.
- Real-time stream data mining, i.e., the process of extracting knowledge models from continuous streams of rapid data records. For deeper analytics, combine historical and real-time streaming data.
- Integrate analytics with data storage. The big data evolution with higher volumes and more heterogeneous data makes analytics even more useful. Develop scalable, sustainable, and cost-efficient data management and analytics architectures.
- Develop new methods to explain and visualise data, using interactivity, filtering techniques, credibility, and open APIs. Study component-based visual editing of apps that utilise open data, social data, and customisable preferences. Employ academically well-anchored but not yet exploited technologies like pervasive computing and embodied artificial intelligence (including large-scale sensors).
- Develop asynchronous, decentralised, and scalable methods and algorithms for mobility data collection and management, with mobility models using a localised distributed approach. Employ trajectory database solutions that are specialised on handling queries related to mobility. Future efficient mining of mobility patterns across spatial and temporal scales will enable new service creation. Composite mobility models may enable a rich ecosystem of mobility-based services and composite services.
- Value-added (i.e., collected, processed, filtered, and personalised) information can help overcome information overloading, especially if the filtering is collaborative and based on trusted sources. Cloud services can extract value and insights, and fine tune them to consumer preferences. User modelling can make clear and transparent consumer lifestyle patterns, which can then inform consumers and producers alike about how to match consumer preferences to what is supplied.
- Creative ways to employ crowd-sourcing can be found through crowd-sourcing itself, all the way up to industry testbeds. Use activity and mobility modelling to make sense of crowd behaviours, and let people become automatic sources of information. Service mash-ups can then be built on top of crowd data.
- Harness human computing powers, i.e., wisdom of the crowd. Use it to, for example, move from *Internet of Things* to things of meaning.

Document Details

Action Line:	TDCT
KIC Activity Name:	Innovation Radar LTU
KIC Activity Identifier:	12185
Task:	T1207A
Catalyst:	Innovation Radar
Deliverable:	D13
Type:	White Paper
Date:	31 December 2012
Status:	Peer review version, M2 (rev. 15 February 2013)
Partner:	KTH
Editors:	Magnus Boman and Kåre Synnes

Contributors

This report was written by **Magnus Boman** (KTH), but for most of the material credit is due to other researchers, developers, and innovators. **Kåre Synnes** lead the bottom-up innovation radar activity in Digital Cities in 2012, and also acted as the executive editor of this report. **Khaldoun Al Agha**, Action Line Leader for TDCT, also provided comments and assistance. While the reference list contains pointers to several Foresight Technical Reports, this white paper builds on the entire activity, which produced more material than the text in those reports. The following experts have contributed to this white paper.

At TU München, **Andreas Möller**.

At SICS, **Olof Görnerup**, **Daniel Gillblad**, **Per Kreuger**, and **Markus Bylund**.

At DFKI, **Markus Löckelt**, **Inessa Seifert**, and **Tilman Becker**.

At VTT, **Tuomo Tuikka** and **Mari Ervasti**.

At U Paris XI (Sud), **Manel Bourguiba**, **Khaldoun Al Agha**, **Hassan Noura**, and **Steven Martin**.

At TU Delft, **Martijn Warnier**, **Frances Brazier**, **Michel Oey**, and **Engin Bozdag**.

At LTU, **Kåre Synnes**, **Matthias Kranz**, **Olov Schelén**, and **Juwel Rana**.

At Ericsson, **Tor Kvernvik**, **Stefan Håkansson**, and **Johan Kristiansson**. Please note that contributions from Ericsson should be seen as individual input and not as officially endorsed statements by Ericsson.

Table of Contents

1 Introduction

This Strategic White Paper is part of the EIT ICT Labs foresighting and business intelligence activities, synchronised by the Innovation Radar, seeks to expose future themes with high innovation and business potential within the thematic Digital Cities of the Future. It is based on a time frame stretching at least 15 years ahead. The purpose is to create a common outlook and to establish a strong community across nodes and partner organisations.

In 2011, the Innovation Radar published three Foresight Technical Reports, all within the Digital Cities of the Future Action Line. At the end of 2012, it was after peer reviewing and editorial work clear that the same Action Line would produce another four, providing the core material for this White Paper. In addition, two more reports were submitted to activity leader Kåre Synnes, and there were also documentation from workshops held in 2012. In addition, a literature study was conducted and a knowledge repository constructed for this white paper, representing deductive research.

The *status quo* of digital cities is analysed in six different perspectives:

1. Social interaction
2. Safety
3. Data management and analytics
4. Mobility
5. Consumer Lifestyle
6. Crowd-based services

Most of the background material in the six reports has been published separately in the EIT ICT Labs report foresighting report series (cf. the References section below). It has been therefore mostly been shredded here, to allow for this white paper to present clear results; crossing over industry, research institutes, and academia. An effort has been made to unify the six perspectives, since there are many overlaps (especially between some pairs, e.g., Safety and Mobility).

While this white paper itself is a static snapshot of business intelligence at the end of the year 2012, the discussion and work is on-going. An important complement to this static report is therefore the dynamic reporting continuously made available through the Innovation Radar business catalyst.

The following three sections are divided into trends, challenges, and opportunities. The strategic picture painted by the respective perspectives needs to be appreciated in order to move beyond the state-of-the-art of the present, into the digital cities of the future.

2 Trends

Understanding current trends is the key to understanding state-of-the-art and what lies beyond it. In the six subsections below, trends corresponding to the six perspectives chosen are described in turn.

2.1 Social Interaction

Rooted in an understanding of social networks [7], the current societal and commercial structures can be understood in part by analysing the relations between people. In particular, relations facilitated and mediated by ICT are analysed in this subsection.

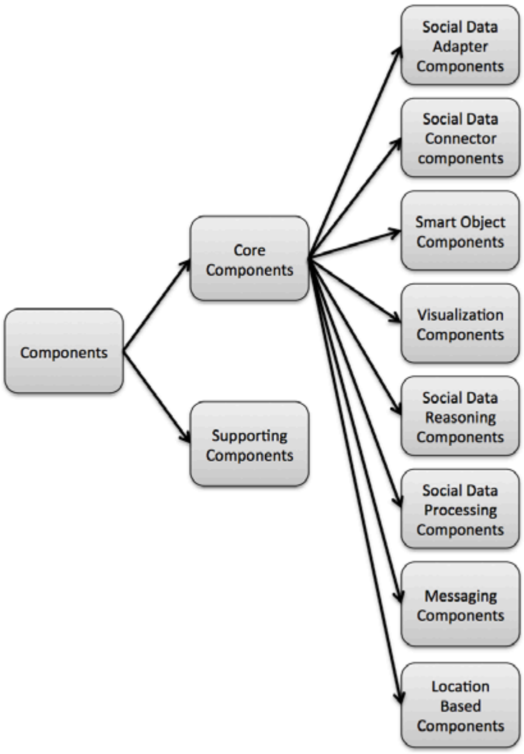

Figure 1: A classification of components for social app development [4].

1. Software structures are constantly evolving towards component-based architectures that support dynamic high-level composition through wrapping and adaptors. By 2016, open component libraries will be available that enable single components to be reused for visual end-user composition (Figure 1).
2. Social data is of ever-increasing interest to app developers, and so is feeding back information to (groups in) social networks. By 2018, creating your own personalised apps based on social data via visual editing will be offered on several platforms.
3. Personalised and customised physical and digital services will in the near future significantly extend and enrich the current mass market.

4. The amount of data sensed (and available for control) will grow exponentially, enabled by the Internet of Things. This in turn gives rise to many challenges regarding capturing, filtering, storing, managing, and utilising Big Data.

2.2 Safety

In digital cities, safety issues are largely about protecting the population. Current trends at any point in time reflect the current threats, many of which are especially serious in large cities. For example, 9/11 high-lighted terrorist activities, the anthrax letters high-lighted bioterrorism, the H1N1 and H5N1 pandemics high-lighted health threats, etc.

1. An increasing number of citizens in digital cities are always on mobile networks. Smart phones are increasingly powerful tools that can act as sensors, and provide information. Geo-positioning applications that can help predict and prevent safety issues are being made available (Figure 2).
2. Sensors are becoming more widespread in digital cities. They feed government databases with early signals and increasingly useful information on how to prevent threats.
3. Services boosting safety in digital cities are moving from call services to multimedia services.

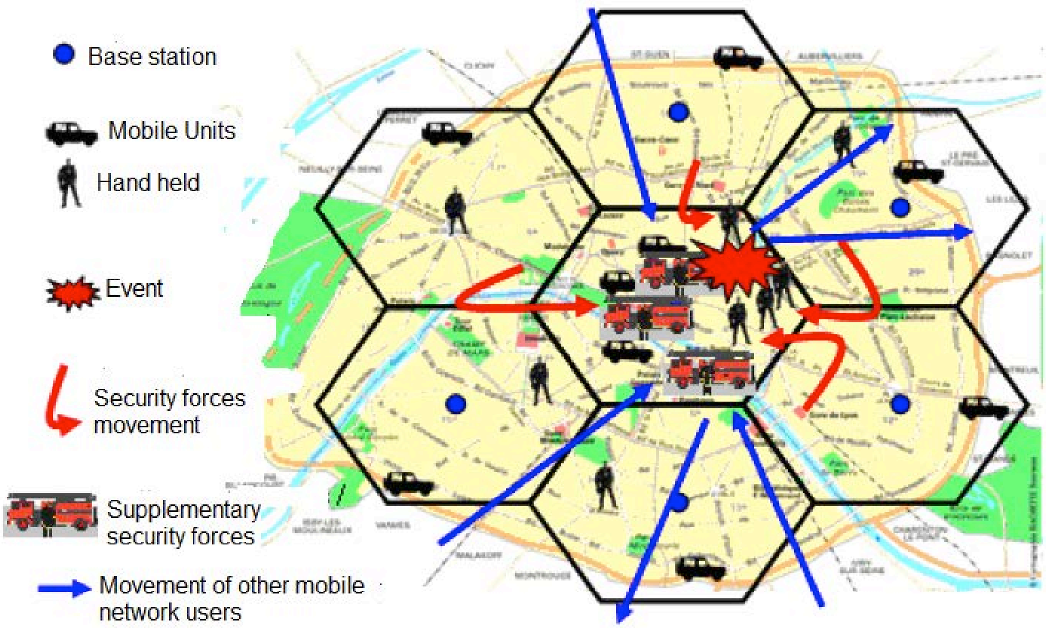

Figure 2: Adaptive Private Mobile Radio (PMR) telecommunications, using portable mobile base station and dispatch console radios, in Paris [2]. The future of PMR goes beyond voice and text messaging into data, images, video, live feeds, database queries, and face recognition.

2.3 Data Management and Analytics

Big data is characterised by the three Vs:

- Volume: larger than 'normal', challenging to load or process
- Velocity: rate of arrival adds real-time constraints to the data management and analytics
- Variety: mix of data types and varying degrees of structure.

The ability to create data is no longer limited to where people are or what they are doing. Now, anyone with a connected device can create data, store it and share it within a few moments. At home, work, and play, people create data, as do stationary objects. Devices and sensors attached to millions of things take measurements from their surroundings, providing up-to-date readings over the entire globe, data to be stored for later use by countless different applications. The most important trends are:

1. Exponential increase in data volume, velocity and complexity. By 2020, the world is expected to generate 50 times the amount of information it did in 2011 and 75 times the number of information containers will be needed to store it [8]. Much of this data will be carried over mobile-broadband networks. Ericsson predicts that by 2017, smartphone data traffic will increase to 1,1 GB per month up from its current 250: a 30 per cent increase [9].
2. Open data, making more data available via open APIs. Both governments and companies are giving access to more of their data. ICT companies share data to enhance their services by enabling new applications to extend and to increase the usage of their services, such as geographical information and social network data.
3. Linked data towards the real world of heterogeneous networks, moving into a world where all data is linked. Data and information are interconnected through machine-interpretable information, as in social networks. Real-world networks are heterogeneous but most of them are today treated as homogeneous networks with single-typed nodes and single-typed links. In heterogeneous networks, there are multiple object types and/or multiple link types. Directly mining information-richer heterogeneous networks gives a richer and higher level of quality output. One example is the Ericsson vision of the networked society, Social Web Of Things, in which more than 50 billion things are connected (see `www.youtube.com/watch?v=i5AuzQXBsG4`).

2.4 Mobility

1. Knowledge of and access to patterns mined from mobility data is potentially the main enabler of a multitude of new information-intensive services and applications that result in improvements in a number of important areas, from telecommunications via transport to societal functions.

2. Mobility patterns and people mobility make possible new ways of accurately measuring exposure to commercial and governmental messages in digital cities.
3. Well-founded estimates of population densities can be made bottom-up, increasing the probability of timely and adequate management of mass events and disasters.

2.5 Consumer Lifestyle

1. Consumers want instant gratification: more information but with less depth. This gives more room for emotions, which in turn creates more impulses to buy (instant gratification). Modern consumers have more information available then ever before, but more options also lead to more choices and less time for in-depth understanding. This shallow content consumption also results from less willingness to spend time on content: the privileged modern consumer no longer lacks money, but time.
2. Online content generation is growing exponentially, as users actively contribute explicit data via online (social) services; data about items and services purchased, about themselves, and about their friends.
3. The advent of cloud computing and other large-scale distributed computing techniques let users outsource their computing needs to third parties. This shifts the online world to a model of collaboration and continuous data creation, a world of Big Data.
4. Online communities, services, and shops have to fight for consumer attention, data, time, and money. This battle for consumers has three parts:
   - Personalisation. Since consumers spend an increasing amount of time online, this trend will spread further in the future.
   - Gamification. The design of services in such a way that they contain gaming elements, like making it possible to win, collect points, or unlock features, is intended to entice consumers.
   - Prosumers. Not only early adopters, but also producing consumers (as, e.g., in energy production/consumption behaviour chains) are openly attended to online.

2.6 Crowd-Based Services

1. Emergence of a new consumer type: the working consumer. Contrary to the conventional role of passive kings to be waited upon, consumers are now becoming more like co-workers who take over specific parts of a production process, whereby this process ultimately remains under the control of an organisation (as, e.g., in retail loyalty schemes).

2. Although there may be challenges in defining the crowd concept, that is, crowdsourcing or crowd-based services, the trend is toward *everyone as a service* [10].
3. Emergence of distributed sensing, using mobile phones, where the sophisticated sensing, processing, and communication capabilities of millions of smartphone users can be harnessed towards a common sensing goal. Distributed data collection from mobile phones and other devices will produce an essential part of Big Data.
4. The rise of social media platforms has shown that people want to create and share their content with others. In the future, this will be included in the *Internet of Things* as a part of social media.
5. Public organisations will provide open data for the creation of new services for smart cities. Cities and public authorities allow generation of open data emerging from crowd behaviour in cities. This enables rethinking of smart cities as learning cities (history and city planning).
6. Big data and open data will enable digital service mash-ups together with crowd-based data, i.e., people producing new information. For instance, energy and traffic data appear in new forms, while the ICT gluing these together can be used to create new service business models.

3 Challenges

Each of the six perspectives present their own challenges, listed and explained in turn below.

3.1 Social Interaction

1. Creating an open platform for component-based visual design of apps requires standardisation. For user-composed and personalised services to become ubiquitous, the challenge is to create an open platform based on recognised (*de facto*) standards.
2. A key technological challenge is to manage to link openly available software components with smart devices and tangible artefacts. This requires open and standardised APIs.
3. Providing Europe with a legal framework for sensors and open data: future digital cities will be providing lots of data to, and will be collecting from, citizens. Before this data can be used for novel services, policies for exploitation have to be defined.
4. Today, more than half of the world population lives in cities. In the future, more people will live in connected mega cities. The rural areas will need to develop services that, if not stopping this trend, at least makes it convenient and possible for the remaining population to stay. This will most probably concern elderly people that are more reluctant to move, and have special needs and demands, such as connected healthcare.
5. Countermeasures must be taken against future 'digital loneliness'. The digital cities of the future must use data to create spaces that foster physical and real cooperation, co-creation, co-living, and interaction. This can potentially also support virtual communities, sprung from a common need or understanding, which may then offer the benefits of smaller communities inside a mega city ('digital villages').
6. Social interaction and responsibility should, using the available data of connected artefacts, be employed to increase the participation of citizens at all levels in society. This would cover all social and societal issues, such as co-governance and future services.

3.2 Safety

1. Citizen behaviour: reluctant citizens may not accept to participate in a sensing or surveillance activity, because of privacy issues.
2. Some citizens are not yet comfortable with using very sophisticated communications systems.
3. Frequency allocation issues, due to the co-existence of PMR with other systems using the same spectrum. Moreover, PMR does not meet the new multimedia service requirements during a security services intervention.
4. Coverage issues and related problems of communication.

3.3 Data Management and Analytics

1. Understanding data.
   - Visualisation. Presentation of the results of sophisticated analysis on large and complex data sets in an easy to follow and actionable format.
   - Interactivity. The user must be in control of what and how to present, by being able to interact with the data.
   - Credibility. There is almost always some degree of uncertainty in data values. The challenge is how to present uncertain data without losing credibility.
2. Data integration. Integration of systems and data is high on the agenda for most organisations. For new applications, for new forms of reporting and analytics, for compliancy and regulatory reasons, for improved customer support, and for numerous other reasons, ICT systems have to work together. Unfortunately, today is replication of integration specifications with no or limited re-use or sharing of resources. The challenge is to present a unified view of all the enterprise data and systems.
3. Scalability. The expected growth of data to manage and analyse will require new scalable and cost-efficient solutions. There will be a requirement for scalable cost-efficient data analytics and management solutions that can support a mix of structured and unstructured data, because of:
   - Processing speed stagnation. Moore's law is not true anymore. Capacity can no longer be met by vertical scaling.
   - The benefits of machine learning and high volumes of data. Learners usually improve by more data. Tools for processing and analysis of massive data are badly needed.
   - Demand for scaling up machine learning is task-specific: for some tasks it is driven by the enormous dataset sizes, for others by model complexity or by the requirement for real-time prediction. To select a task-appropriate parallelisation platform and algorithm requires understanding of benefits, trade-offs, and constraints.
4. Accelerate time to insight. The number of data sources increases, which makes it harder and in some cases infeasible to store every piece of data. Actually, the amount of available storage capacity will not be enough in order to record all the digital information generated in the world and this could become one of the main triggers for a paradigm shift. Another aspect is that it is necessary to react instantly to meaningful changes in data, and detect complex patterns over time.

5. Monetise on new types of data. Still most of the revenue is generated from traditional structured data although the volume of data is mainly increasing in new areas, e.g., unstructured data, social networks, apps, web search tools. Facebook has about 800 million updates per day, for example, and that huge amount of data in contrast of what today is a modest online advertising business, worries privacy-conscious Web users. Everyone has a feeling that this unprecedented resource will yield something big, but nobody knows quite what.

3.4 Mobility

1. The possible ramifications of unreflected exploitation of user data on issues like privacy and information security are enormous. Mobility information can be extracted from a combination of several more or less isolated systems managed by different stakeholders. Each such system will in general contain information that the owner of that data will not be willing, able and/or legally allowed to distribute or exchange with others.
2. Patterns inferred from mobility data may reveal sensitive information, such as the whereabouts of individuals or groups of individuals. However, the owner of the user data may also be prepared to disclose a certain aspect or aggregate of the data to another stakeholder. Doing this robustly and securely poses several crucial challenges for systems design and business model development.
3. As the rates of data and meta-data increase, the allocation of network and configuration of network parameters will become a major problem for the network operator. This is a critical problem for the telecom industry that needs to be addressed. Mobility patterns are central to efficient resource management in information-intense networks on which new information intense services and applications rely.
4. Mobility data is also typically hidden in other types of logs that are generated in extremely high volumes from separate, distributed sources. Therefore, information about the huge, disparate and complex sets of user data will probably need to be distributed and processed in a decentralised manner, which in turn poses challenges for efficient data aggregation, integration, management, and user data modelling.
5. Collected mobility data must be stored in a scalable manner. Traditional database solutions are neither sufficient nor optimised for space and time data, and are unsuitable for managing time-stamped raw location traces. This type of data requires solutions that effectively handle continuously changing information, e.g., the trajectory of an object, by utilising the spatial and temporal constraints associated with mobility data. Integrating multiple mobility data sources is associated with several additional challenges, as the system must be able to handle data with varying interpretation and resolution, both spatially

and temporally, due to differences in sample rates and measurement resolutions, for example in GPS-, cellular network- and Wi-Fi data.

6. Data sources may be statistically skewed or biased with respect to each other, or for a particular application. As an example, when considering GPS data from mobile devices, one has to take into consideration that people carrying GPS-equipped mobile devices may not constitute a representative cross-section of the population as a whole. This requires a certain focus on developing methods for a statistically sound integration of data, e.g., using standard resampling techniques.

3.5 Consumer Lifestyle

1. Even though the amount of generated data has increased exponentially, human capabilities for absorbing information have not. Because the information processing abilities of the mind are limited biologically, people tend to get overwhelmed, as in information overloading.
2. The right to privacy is not absolute and uniformly adhered to. Even in cases where legal privacy regulations are in place, it can still prove difficult for citizens to claim their rights in practice.
3. New ways of monitoring consumer lifestyle require an expensive investment into infrastructure. The fact that very few players can afford such investments, there is a risk of vendor lock-in.

3.6 Crowd-Based Services

1. Each new digital service requires adequate identification of future, not just current, user needs.
2. Crowd-based services must be delineated, for example in a passive (Big Data) vs. active (user behaviour) dichotomy, to correctly identify business opportunities.
3. Big data analytics, making sense of data in intelligent ways, is needed for value-added services.
4. Naïve crowdsourcing can lead to herd behaviour rather than collective intelligence. Coordination is often necessary, and critical mass must be attained.
5. Current *Internet of Things* solutions are fragmented and target specific vertical domains and/or specific types of applications. Interoperability and standardisation efforts are required.
6. Innovation ecosystems for the digital cities of the future have to be defined. Concrete steps include revenue stream identification, public/private partnership brokering, countering the pains of ever-increasing urbanisation, and open data being made available to developers and user communities.

4 Opportunities

The following actions can and should be taken to ensure early adoption and make possible first-mover advantages for partner companies and organisations in EIT ICT Labs.

4.1 Social Interaction

1. Study component-based visual editing of apps that utilise open data, social data, and customisable preferences, such that personalised apps for smart devices can be easily constructed by any end user (cf. the ICT Labs-supported company *MoSync*).
2. Push judicial issues, standards, and policies for citizen rights to privacy.
3. Push standards for middleware and service APIs to allow for the interconnection of services and data, while ensuring trust. This will include the need for modelling and developing a transparent layer for future digital cities and economies [6]. It will also involve and employ Internet of Things technology solutions.
4. Employ academically well-anchored but not yet exploited technologies like pervasive computing and embodied artificial intelligence (including large-scale sensors).

4.2 Safety

1. New ways of sensing the environment are being made available, and may be employed, if accepted by citizens.
2. An efficient PMR could be based on LTE radio technology. Network coding could be adopted to further improve PMR performance, robustness and security, offering high potential for security business.
3. Frequency allocation optimisation: dynamic optimisation mechanisms that allow for a selective allocation of the services with regard to the current requirement and the opportunistic possibilities of accessing the radio resource.
4. Deploying ad-hoc networks to mitigate coverage issues.

4.3 Data Management and Analytics

1. Real-time stream data mining, i.e., the process of extracting knowledge models from continuous streams of rapid data records. The knowledge model is continuously updated to adapt to sudden changes. The data stream paradigm was born as an answer to the continuous data streams that cannot be stored and analysed in an efficient manner. Data stream mining can handle bigger data sizes than what fits in memory and can extend to challenging real-time applications not previously tackled by machine learning and data mining techniques performed on historical data. It is useful when:

- the concept drifts often and there is a need to react very fast to changes, e.g., when using weather forecasting for the prediction of electricity generation and consumption.
- the *store everything* approach combined with the increase in number of data sources makes it harder and harder to manage with the available data storage.

2. For deeper analytics there will be a need to combine historical data and real-time streaming data. The time window that the real-time stream data mining analyses is limited both in number of data elements and the time window analysed. For example, sensor data and transactional data can be analysed in real time streams to detect unexpected behaviour. This can then trigger data mining on historical data to detect deeper understanding of the events that caused this unexpected behaviour.
3. Integrating analytics with data storage. Today, data analytics and data storage are treated as separate research areas and are many times separated in the products. Siloed research and products can in many times lead to missed opportunities and performance bottlenecks. The big data evolution with higher volumes and more heterogeneous data makes analytics even more useful. Integrated analytics and data storage will become mainstream business requirements.
4. New data management and analytics architectures. Future data management solutions need to:
   - transparently map multiple autonomous databases into a single federated data base system
   - support a mix of structured and unstructured data
   - be scalable
   - be cost-efficient
   - be environmentally friendly

   Super computers will not be sufficient: increased parallelism will be required.
5. User-controlled privacy: the user needs to be able to easily control the level of privacy. If the end-user knows what type of information is stored in the system and what information is shared with others, the threshold for accepting new services is reduced. Clear policies about what can be shared also help reduce the threshold for new applications.
6. In order to make the knowledge derived from the large volumes of data valuable, new methods to explain and visualise the data will be required: new ways of presenting information are needed.
   - Interactivity. The end user must be able to interact with the data by clicking, querying and eye movements.

- Filtering techniques. Personalised filters that can be modified and that learns from experience what the end user needs.
- Credibility. The credibility of the information can be improved by clearly visualise the level of uncertainty in the information by for example confidence intervals.
- Open APIs to data sources are increasingly important ingredients of contemporary data visualisation.

The increased data volumes and the new data types that will be available in the future yield an opportunity to get a business edge over other players. The value of the information in the data is significant, but the cost involved obtaining it using current technology is inhibitive. Consequently, new technologies will be required to leverage the value from the data.

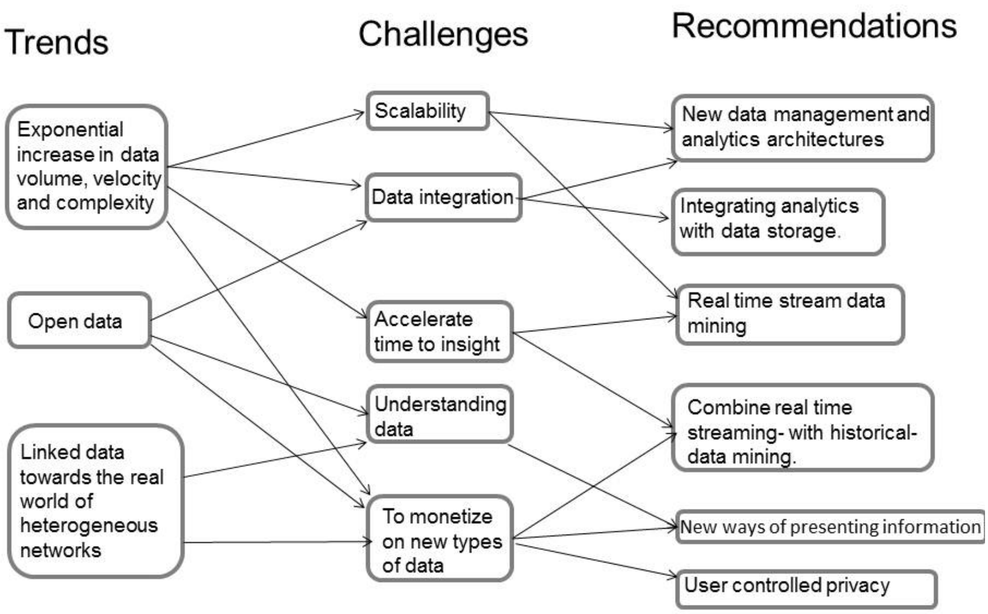

Figure x: A summary of recommendations based on the opportunities within data management and analytics [3].

4.4 Mobility

1. Applications can be built by third parties, based on information and models provided by several other parties, such as network providers and social network stakeholders. Such a scenario has the potential to develop into a thriving market of application developers, technology suppliers, and service providers. Public and commercial access to such a platform would offer countless opportunities for innovative services that reuse currently unexploited user data sources, enabling improved urban planning, epidemiological applications, traffic planning, and monitoring, as well as improved management and resource planning for communication networks.

2. Trajectory database solutions now exist that are specialised on handling queries related to mobility, such as *find the object that is closest to a moving object within a certain time interval*.
3. Scalable methods and algorithms for mobility data collection and management, with mobility models using a localised distributed approach, would provide support for a system protecting privacy by representing collective rather than individual behaviour.
4. Future efficient mining of mobility patterns across spatial and temporal scales will enable new service creation. Composite mobility models may enable a rich ecosystem of mobility-based services and composite services.
5. Future asynchronous and decentralised algorithms for mobility data aggregation and dissemination can be adaptions of existing methods for data collection in large-scale and dynamically changing systems, such as gossip-based algorithms, where data disseminate by stochastic or *ad hoc* exchange of information between neighbouring nodes.

4.5 Consumer Lifestyle

1. Value-added (i.e., collected, processed, filtered, and personalised) information can help overcome information overloading, especially if the filtering is collaborative and based on trusted sources. Cloud services can extract value and insights, and fine tune them to consumer preferences.
2. User modelling can make clear and transparent consumer lifestyle patterns, which can then inform consumers and producers alike about how to match consumer preferences to what is supplied.

4.6 Crowd-Based Services

1. Creative ways to employ crowd-sourcing can be found through crowd-sourcing itself, all the way up to industry testbeds.
2. Harness human computing powers, i.e., wisdom of the crowd. Use it to, for example, move from *Internet of Things* to things of meaning.
3. Use activity and mobility modelling to make sense of crowd behaviours, and let people become automatic sources of information. Service mash-ups can then be built on top of crowd data.

References

[1] Matti, M and Kvernvik, T; Applying Big-Data Technologies to Network Architecture", *Ericsson Review*, October 2012. www.ericsson.com/news/121003-applying-big-data-technologies-to-network-architecture_244159017_c?categoryFilter=ericsson_review_1270673222_c

[2] Bourguiba, M and Al Agha, K; Safety of the Digital Cities, Foresight Technical Report, EIT ICT Labs, TR2012-009, December 2012.

[3] Kvernvik, T; Data Management and Analytics for Digital Cities, Foresight Technical Report, EIT ICT Labs, TR2012-005, December 2012.

[4] Synnes, K, Kranz, M, Schelén, O and Rana, J; Social Interaction for Digital Cities, Foresight Technical Report, EIT ICT Labs, TR2012-008, December 2012.

[5] Tuikka, T and Ervasti, M; Crowd-based Services for Digital Cities, Foresight Technical Report, EIT ICT Labs, TR2012-006, December 2012.

[6] Arthur, W B; The Second Economy, *McKinsey Quarterly*, October 2011.

[7] Newman, M E J; The Structure and Function of Complex Networks, *SIAM Review* **45**: 167-256, 2003.

[8] Gantz, J and Reinsel, D; Extracting Value From Chaos, IDC, June 2011. www.emc.com/collateral/analyst-reports/idc-extracting-value-from-chaos-ar.pdf

[9] Gilstrap, D; Traffic and Market Report, Ericsson, June 2012. www.ericsson.com/res/docs/2012/traffic_and_market_report_june_2012.pdf

[10] Petrie, C; Plenty of Room Outside the Firm, *IEEE Internet Computing* **14**(1): 92-96, 2010.

Imprint:
EIT ICT Labs IVZW
22 Rue d'Arlon, 1050 Brussels
BELGIUM

ISBN 978-91-87253-09-6

Innovation Radar