National Sensor Registry a Step Forward

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Key words: sensor, network, registry, citizens participation, blockchain, IoT.

SUMMARY

National Sensor Registry is an instrument that increases the transparency about the sensors in the open space and the purpose of their measurements. It provides information about a sensor and its data location, so that the interested parties can reuse the existing data. In the last few years there have been a lot of initiatives that aim at different aspects, such as technical, organizational, social involvement etc. of creating National Sensor Registry.
For example, one of the initiatives aiming at social involvement was a "sensor walk". A “sensor walk” was an activity to increase the awareness about the growing number of sensors in public space and to increase the collaboration of citizens by collecting data about the sensors.
Because of the involvement of many stakeholders in the National Sensor Registry development and the possible growth of the community, an open collaboration model was chosen. Everyone was encouraged to add new topics, issues and review the contributions of others. A decentralized system assured the needed flexibility for every stakeholder. Each participant was managing his own data, the metadata about his sensor devices, in his own Registry Node connected to a shared network. The requirements for a decentralized transaction management system and solution for the network exchange, supported the choice for ’Blockchain’ technology.
Although all parties support the common need and shared approach for building the National Sensor Registry, each party has their own priorities, focus and challenges. Even though the final solution has not been implemented yet and the legislation needs certain adjustments, several milestones towards National Sensor Registry are realized.

National Sensor Registry a Step Forward

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1 INTRODUCTION

Every smart and modern city nowadays is full of sensors, cameras and measuring devices. A sensor generally refers to a device that converts a physical measurement into a signal that is read by an observer or by an instrument (Chen, et al., 2012).
There are many types of sensors, and they vary in functions and applications. There are types supporting a life comfort such as sensors located in the parking spaces to support the communication flow or the one that opens doors automatically. Those sensors are used for a demarcated reason and are not collecting or sharing any data. Another distinguished group are the sensors located in public space which are collecting a whole variety of data. Those sensors are usually fixed to objects like lampposts or hanging on the building walls.
The rapid and large increase of sensors in public space has raised questions among many citizens such as: What do sensors measure and with what purpose? What happens to the collected data? Who is the owner? Where are they exactly located? For many municipalities this triggered the urgent need for more transparency about these objects. The municipality is in fact the guardian of the public space and responsible for public order and safety. Moreover, there are plans to oblige municipalities to publish the sensors that bring risk to the people's privacy. Citizens should be able to get information about where they are 'sensed' at every location in their city. A registry of sensors makes this information available to all community: citizens, companies, researchers and the government itself.

2 NATIONAL SENSOR REGISTRY

National Sensor Registry (NSR) is intended for everyone who uses the public space. It is an instrument that gives an insight into sensors, their owners and the reason of the measurement in the public space. It also offers the government opportunities to set conditions for the installation of sensors and gain insight into their collected data. In the Netherlands the first steps towards the NSR have already been made. One of them was a successful pilot developed by the municipality of Eindhoven in cooperation with The Netherlands' Cadastre, Land Registry and Mapping Agency – in short Kadaster.

Kadaster has been responsible for real estate registration and geo-information since 1832. As an implementing body of The Ministry of the Interior and Kingdom Relations (BZK), it is committed to fulfilling this role in the manner expected by law, the stakeholders and society. Kadaster contributes to social issues and responds to digital developments. The appearance of sensors in public space is an example of this. The physical living environment mixes with the digital one. The challenge for Kadaster and other governments is to organize the data, as well as the knowledge about the data, in such a way that added value is realized in society. A connection is made with existing data infrastructures such as the basic registrations and the

National Geo Information Infrastructure (NGII). Kadaster is continuously working on the digital future of the living environment.

The first prototype of NSR has been built of many components. One of them is the central viewer (Fig 1) that provides a digital map with locations and all additional information such as what sensors measures and why.

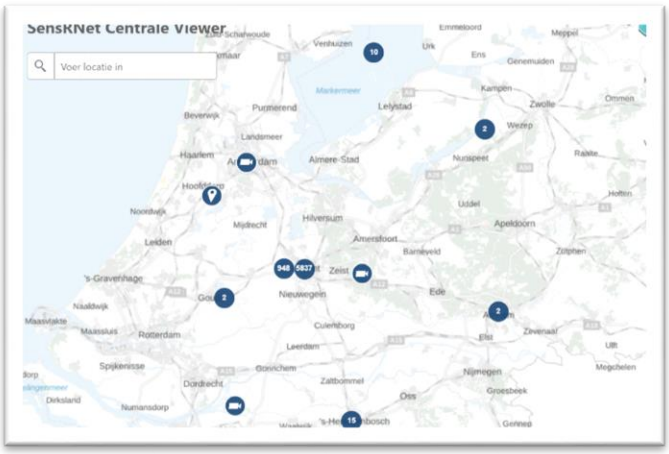

Fig 1. Central Viewer (https://viewer.sensorenregister.nl/)

2.1 What problem can be solved

National Sensor Registry prototype has been created based on five principles for the digital society, defined by the Association of Dutch Municipalities (VNG) members during the general members' meeting on November 29, 2019 (VNG Realisatie, 2019). These principles can get practical value only when they will be translated into useful instruments.
The next section explains how the NSR prototype relates to these principles and what problems can be solved by means of this tool.

Principle I: Social values
With the insight into sensors and their owners in the public space, it will be possible for municipalities to manage the principle that the data collection and their usage must serve the public interest and contribute to the quality of life in the villages and cities. The NSR enables municipalities to take control and achieve these requirements.

Principle II: Organized rights over data
With the insight into sensors and their owners in the public space, it will be possible for municipalities to comply with the open data principles and related rights and obligations regarding data collection and its usage.

Principle III: Accessible and safe infrastructure
By means of NSR it will be possible for municipalities to provide an easy and safe access to public data for everyone interested.

Principle IV: Connected parties
By means of NSR it will be possible to provide an insight where the sensors are placed and what has been already measured, so that the interested parties can reuse the existing data and at the same time prevent the cluttering of the public space.

Principle V: Transparency central
An insight into sensors, their placement, aim of the measurement and the ownership, increases the transparency among the inhabitants. The NSR gives citizens and companies an accessible tool to exercise their rights, such as requesting which data may have been collected about them by others.

3 HOW DID IT START?

In 2017 the initiative was started to map sensors in one of the popular entertainment streets of Eindhoven – Stratumseind. Stratumseind is well-known for the various pubs, cafes and restaurants. It is also seen as living laboratory where many organizations work together to make the street safer and improve the living environment. The street is full of measurement devices like cameras and sensors. The visibility of the measuring equipment and lack of transparency about what is being measured by whom and why were often a point of criticism. The required transparency about sensors in public space was a key motivator for Eindhoven to take part in a sensor registry project. With sensors getting cheaper and more common, a transition has taken place in the government of the municipality of Eindhoven. The principle was to keep the data closed if there was no clear need to make it open. This perspective has gradually turned into publishing all data as open data, unless there are clear restrictions of use of the data.

The “sensor pilot” was a working prototype of a website where the registration of sensors as well as making them visible on the map (Fig 2). In Eindhoven, the Sensor Registry turned out to represent an important trend in society: the demand for publicly available data about the living environment.

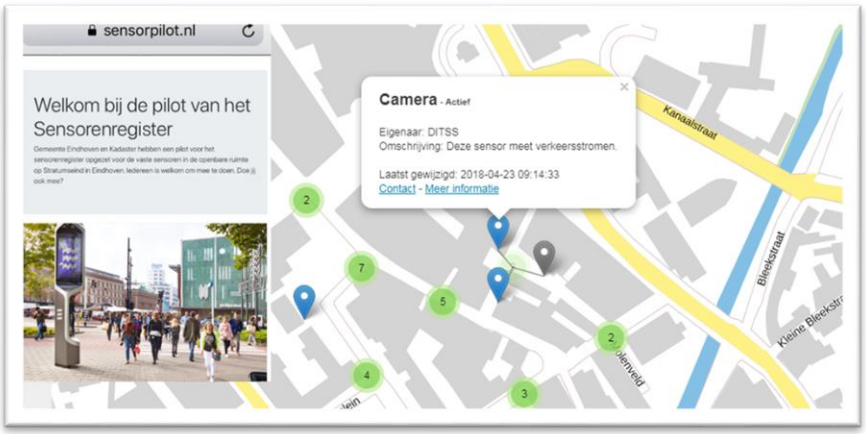

Fig 2. Sensor Registry pilot by Kadaster and city of Eindhoven

Due to the concrete realization of the prototype, the concept was shared, and the ideas grew into new innovations and collaborations.

4 INCREASING AWARENESS & "SENSOR WALK"

Eindhoven is an example of a city with a smart society. This smartness is visible in the involvement of city, residents and companies together in co-creating the living environment. The Dutch government has stated that collaboration with citizens is something that should be adopted. Moreover, the new Environmental and Planning Act (come into force on 1 January 2023) creates a legal basis for citizens' involvement and co-creation of the public space.

To improve this involvement and increase the awareness about the growing number of the sensors in the open space, the curriculum "sensor walk" was created.
The curriculum materials were prepared by the pilot group from Kadaster and is intended for students, citizens, school children and participants during various conferences.
The curriculum consisted of three parts. The first part included theory, problem definition and explanation of the context of the NSR project. The most important definitions were explained as well as definitions of the sensors and IoT (Internet of Things). The second part was intended to walk, spot and collect as many sensors as possible in their neighbourhood. A dedicated, user-friendly application was created. It was built by means of ArcGis Online (Esri) software, where everyone who had a mobile phone could easily use it (Fig 3).

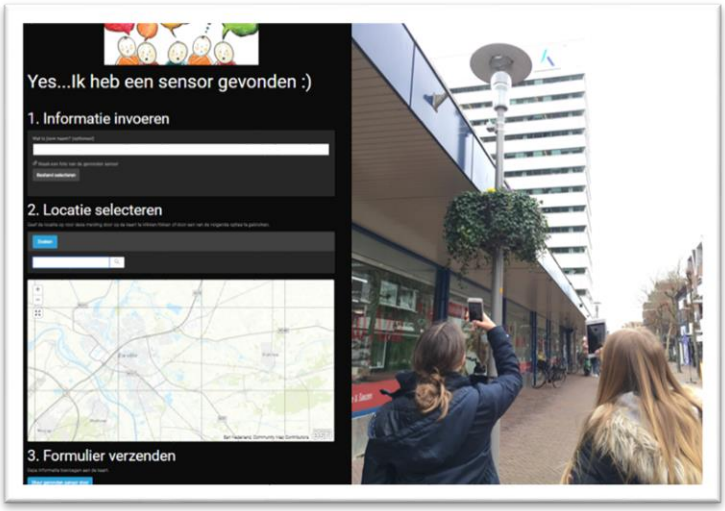

Fig 3. Application for collecting sensors

The last part of the curriculum focused on data collection, analyses and the feedback from the participants. To visualize the collected sensors, their location and concentration was included in a web dashboard (Fig 4).

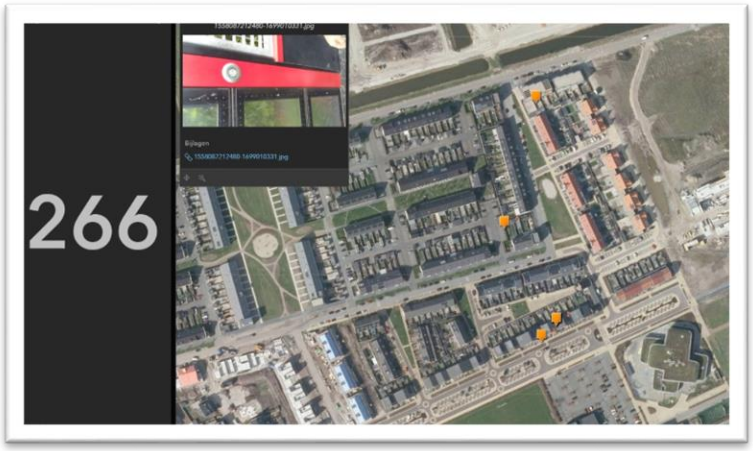

Fig 4. Dashboard with collected sensors visualization

From the collected feedback, we have learned that participants were not aware of such a big number of the sensors in the public space. The large number of collected sensors presented on the dashboard was a big surprise for most of them. The participants highly appreciated the (inter)active part of the curriculum. Walking around and spotting sensors in the neighbourhood was a nice variation comparing to the classical curriculum. Although the curriculum was tested with a limited number of people, we increased the awareness of the participants about sensors located in the open space. The curriculum helped in spreading knowledge about the rise of sensing technology and the changes that are taking place in our surrounding nowadays. It also leads to a valuable discussion about the privacy, transparency and responsibilities that the government should take. All participants agreed that the involvement of citizens plays a crucial role in creating public space and many of them expressed the eagerness to be a part of co-creation of the living environment in the future.

5 A MINIMUM VIABLE PRODUCT

With the growing awareness and growing community of governmental parties the common need for a working system that would provide information about ’sensing’ in the public space has increased. The Kadaster was asked to develop an initial system for the National Sensor Registry.

5.1 Organizational

The project focused on maximum involvement of the stakeholders on the management and executive level. The governance initiation group was responsible for scheduling, adjustments, accepting milestones and financing. The functional advisory board has been in the lead for the functionality of the NSR. Suggestions about functionality as well as system requirements were discussed and shared with the development team of Kadaster twice a month. With the help of a digital project board accessible on GitHub (Kadaster, 2022), everyone could add topics, issues and judge the contribution of others. The development team consisted of five Kadaster employees with different background and responsibilities: developers, an architect, a

product owner and a Scrum-master. Once a week they joined the weekly stand-up as is common in Agile practices discussing the development and extension of the register.

When the register will transform into a real operational phase, the involved community will be expanded. There will be a community manager needed to take care for a good relationship with educational institutions, local or national governments as well as citizens.

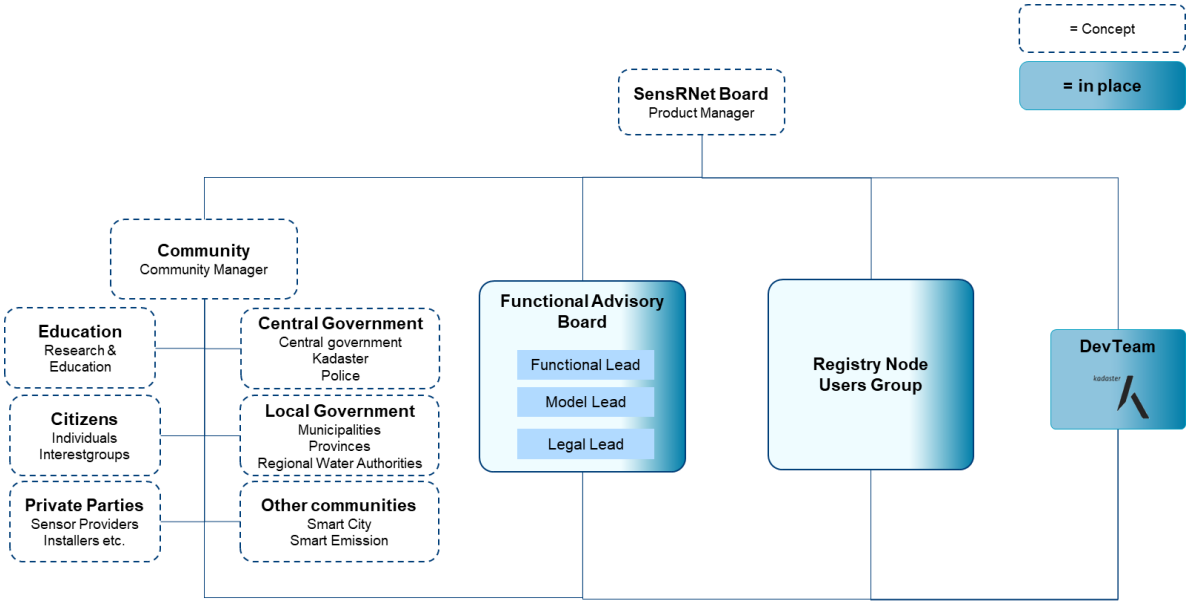

Fig 5. Organization of the project

5.2 Technical choices

The technical solution consists of three parts: 1) Local Registry Node (or tool), 2) a Central Viewer and the 3) Network to connect all nodes. This is described in great detail by (Andel et al 2021). A short summary of this description follows here:

A few key concepts set the base for the system layout. These key concepts were to address the needs formulated within the community of stakeholders. Because of the variety of stakeholders, each with their own perspective and focus, the system should be very flexible. The number of stakeholders requested a very scalable system. A few principles had to be followed such as architectural principles of the VNG as well. All this resulted in the following key concepts:

1. Decentralization as given
2. Event-driven (and Event Sourcing internally)
3. Data at the source (with the respect of events as the origin of data)
4. Privacy by design
5. Open collaboration – like Open Source and Open Standards

A decentralized system addresses the needed flexibility per stakeholder. The system consists of a Registry Node per participant in the network. Each participant is managing his own data, the metadata about his sensor devices, in his own Registry Node. The Registry Node is than connected to a network of Registry Nodes and by doing so sharing the public data of all registered sensors. This creates the possibility for a different kind of node like a Publishing Node. This node is connected to the network in a similar way but in this node no changes can be made to the data. The Publishing Node only consumes the shared data in the network to publish the whole in a Central Viewer. This is the official publication of sensor devices on a map.

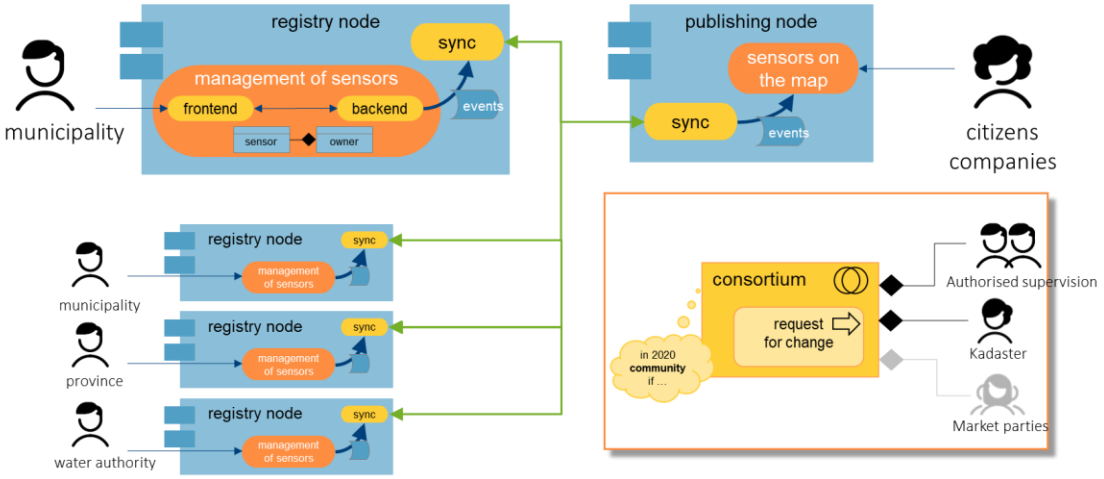

Fig 6. Solution architecture

The actual data exchange is based on the exchange of the changes of the metadata about sensors. Changes arise in a specific Registry Node in the execution of the maintenance of the metadata of sensors. All changes are posted on the network as transactions and shared among all nodes. This requires a decentralized or distributed transaction management system and sounds like a distributed ledger. Exactly for this reason a Distributed Ledger Technology, a DLT or in general 'Blockchain', is applied as solution for the network exchange. Changes in the form of events explicitly contain the origin of their existence and the timestamp. This addresses the key concept of knowing where data originated, so data is kept at the source. By sharing the events as transaction on a DLT the availability of data in other nodes can easily be guaranteed. For example, in the Publishing Node the registry of current and actual sensor devices is prepared and directly available for viewing and querying. With live updates with new events and the governing technology of the DLT guaranteeing high performance delivery between all nodes, the Publishing Node is updated within second after changes are made in any Registry Node.

All metadata of sensor devices is registered to known users. Users belong to an organization for which they register the devices. These organizations are the owners of the devices and published as such in the Publishing Node. The user information is privacy sensitive information and should not be shared and/or published in any way. Changes and information

about users are available within a Registry Node of course but these events are not shared in the network. By doing so the principle of privacy by design can easily be accomplished.

Because of the needed flexibility and the involvement of many stakeholders and possible growth of the community an open collaboration model was needed. By applying open source to the project an open collaboration was stimulated from the start and this promoted the wide collaboration. The product development and roadmap were enriched by contributions from many stakeholders even less involved members. Contributions of stakeholders without direct commitment enriched the product and roadmap of the development during development.

6 CHALLENGES

6.1 Legislation and regulations

As in every developing project we can observe a different speed of recognizing the need for creating rules about – in this case – exchanging sensor metadata among local governments. This can be done either by national legislation or by local regulations. In the Netherlands there are 344 municipalities, varying in population between only 1000 to nearly 900.000 inhabitants. Generally, the bigger cities are more specialised and more involved to take sensor activities under their control. In spring of 2022 the city of Amsterdam was the first with specific regulations regarding the use of sensors in public space. Public and private companies in Amsterdam sensing public areas must inform their local authority about details of sensing activities such as sensor type, location, use of personal data and the expected duration of sensing. This metadata is published by the city as a part of the National Sensor Registry initiative. It is expected that other cities will follow with their own (similar) regulations. There are also many discussions throughout the stakeholders about switch from the sensor's report obligation to license obligation.

Local regulations can be seen as a first step towards a national legislation. Although this still must be worked out, two areas of focus can be distinguished:

1. Duty on informing (local) authorities when sensing public space as an extension of local initiatives
2. Compulsory use by (local) authorities the registration of sensors in the public space

Early adaptors like big cities should be able to apply local legislation and support this with sharing data via the NSR. Other cities should be able to develop at their own pace. Nonetheless, whether you join the NSR at the start or at a later stage in time the moment you start sharing, the data should be of high validity and quality. For Kadaster as a central administrator serving the publishing node it is crucial that the data can be trusted by every user. This means that being part of the NSR community obliges the participants to keep their data up to date and validated accordingly with agreed standards.

Creating a new national legislation takes a long time; a minimum of two years must be considered. This legislation can not only be used to clarify the rights and obligations of sensor owners but can also to arrange the governance to provide the National Sensor Registry. It is likely that a coordinating role of the Ministry of the Interior is necessary to enable a National Sensor Registry. Other conditions as financing, liability, data-ownership, data modelling, standards and relationship to the Dutch Key Registers must be arranged between all stakeholders separately.

6.2 Mobile Sensors

For the current National Sensor Registry, the scope is limited to sensors at a fixed location. Of course, it is possible to relocate such a sensor but still this is a manual administrative work. For mobile sensors the NGR is currently not applicable. Mobile sensors need to be registered at some point in time, but they require a very different approach on what to register, how to register and how to publish their location on a map. Should it be (near) real time? Should it be an area of operation? Should it contain historical tracing of its locations? These kinds of sensors, the objects they are connected to and the dynamics around them is a challenge of a different kind. Probably other stakeholders and experts need to be involved to address this challenge.

6.3 Smart Sensors

Analog sensors still exist and are applicable for the National Sensor Registry. But electrical empowered sensors are more relevant for their capabilities. And these capabilities are still growing. Sensors are becoming little computers with rich interaction and measuring possibilities. Sensors are becoming Smart. For electrical empowered sensors the sensor data is already digitally available. Part of these sensors' data might be some of the metadata included in the National Sensor Registry. Many sensors already contain a GPS chip besides their main purpose to measure some physical phenomenon. Their location is included in the sensor data they produce.

At some point in time these Smart Sensors might be able to register themselves to the network. A National Sensor Registry system should be open to these developments although it is currently in an early stage on how this should be working. There are multiple IoT platforms for collecting and publishing sensor data. These platforms also provide DIY libraries to easily integrate with the platform and provide metadata about the sensor itself. These platforms are cloud providers as well as blockchain networks.

Because of the variety and richness of solutions currently being in development it is and will be a challenge to provide opportunities for integration, growth and expansion of the National Sensor Registry. Questions such as: How do relatively traditional processes within the government should address the state-of-the-art technology developments of IoT? or how to make it possible for a Sensor Registry to provide enough features and stability on one hand and still be open to new opportunities? Should be addressed very soon.

7 DISCUSSION

7.1 Governance and responsibilities

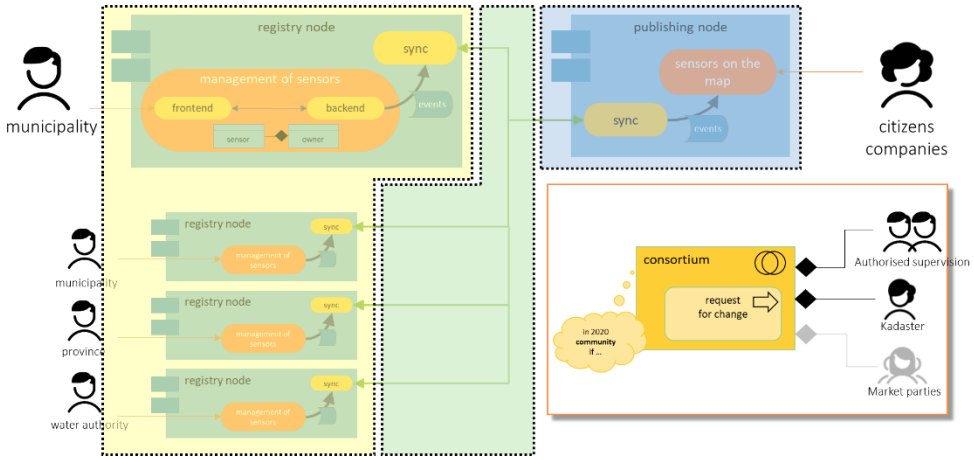

Fig 7. Responsibilities

With the decentralized set up of the National Sensor Registry, a new responsibility came up. Like in other national registries two separate parts do exist in this architecture as well. One part is the decentralized system in which each municipality or other responsible party maintain the information about sensors. The other part is a national publication point – the Central Viewer – at which all gathered information is being published. With the Sensor Registry set up the shared part for the exchange of data between the decentral nodes and the Publishing Nodes has become a separate responsibility. And with that a new quest for the governance of this shared infrastructure arises.

All other registries have some sort of collaboration agreement about responsibilities and about the APIs for exchanging data. In this case this last part also has a single implementation set up as an Open-Source project. So, the data exchange consists of the specifications as well as the implementation in working software. The responsibility for this shared infrastructure requires knowledge about the subject, in this case the metadata of sensors, as well as knowledge about exchanging data *and* technical knowledge to automate all this into working software.

The discussion about the shared data exchange part is whether this is a shared responsibility which should be worked upon by all stakeholders; or should this responsibility be delegated to a single stakeholder with collaboration structures to manage all requirements; or should a new or separate entity be formed for this responsibility? And what governance structure should support whatever option will be decided to?

7.2 Tuning challenges between board and execution

The Sensor Registry is set up as an open collaboration project. A new community was formed by all parties which are involved in an open manner. Although all parties support the common

needs and shared approach on building the National Sensor Registry, each party has their own priorities, focus and challenges. The development of the Sensor Registry was executed by a software development team at Kadaster. Steering of features and priorities was delegated to the community. Because the community was newly formed and was developing during the project period, sometimes it was hard for the project board to respond on time. For the government the governance of an open collaboration project is quite new and asks for other and new governance forms which need to be developed during the development of an actual system. For example, the technical development of the Sensor Registry had a higher pace than the governmental part. Also, the discussion of positioning the NSR near to the Dutch Key Registers is taking place right now and will influence finance, governance, modelling and content of the Registry.

7.3 Blockchain growth variations

The use of blockchain generally provokes reactions, especially by blockchain critics. There are aspects it is good to be aware of when applying blockchain as a solution. For example, the fact that nothing can be deleted from the blockchain. In general, this is valid and even desirable, but in case of mistakes, error situations or privacy leaks by misuse of fields this might become an issue. The application of blockchain is relatively new to the IT industry and we need more time to consider how to apply blockchain appropriate. For the Sensor Registry we see mainly two options: less blockchain or more blockchain.

Less blockchain means that the technical application for blockchain is of too much risk or costs and it has to be replaced by some other distributed or decentralized solution. In fact, the blockchain is currently used as a decentralized database and there are other solutions available on the market. Because the distributed ledger is simply applied as a technical layer it is quite cheap to implement some other technology here.

More blockchain means that more blockchain concepts will be applied to the system. This might be an obvious direction as well. Currently the data which is shared belongs to a specific Registry Node but actually it should be owned by the owner of the sensor. This is also registered but as a separate entity within the data and not connected to the Registry Node that it is registered in. This leads to a mismatch between ‘Owner’ of a sensor and Registry Node. It also causes a complex management for bigger organizations in case they need to exist in multiple Registry Nodes or might migrate from one to another.

A wallet is a common blockchain concept which fits here quite nicely. Each owner of one or more sensors needs to have a wallet in which he can manage the data he would like to share. This enables private data even more than in the current set up. One step further might be that even sensors themselves have a wallet and connect to the blockchain autonomously. With the rise of Smart Things and sensors with compute power this will become more and more applicable. The ownership of this sensor can then be claimed using the wallet of the owner in which additional information can be shared about the purpose of the sensor and so forth.

So, this discussion is about the direction of development of this decentralized ecosystem. On the one hand blockchain is debatable and should be evaluated closely. On the other hand, blockchain and its aspects of decentral management and sharing of data is very much applicable and fits very nicely. Experience with the current system will help to decide which direction is the most fruitful and best fit. This will also be influenced by the common perception and shared knowledge about this technological area.

7.4 From innovation to mainstream operation

Five years ago, the journey of the development of NSR started. Since than a lot of experiments, product development and knowledge exchange about sensors and metadata have taken place. Due to the advanced technological developments, it is expected that the NSR will be able to adapt to future phenomena such as self-registering and mobile sensors. Another challenge will be the interplay between public and private parties, for example which conditions and restrictions should be implemented by government for private parties that are monitoring the public space and how the growing amount of information from the sensors should be managed?

The phase of innovation is already behind us, but a stable environment for management and orchestration does not exist yet and must be formed. This environment should accommodate various interests of many parties including clear task division, governance, finance and responsibilities. The need for National Sensor Registry is not up for debate. It is hoped that with a cooperation and commitment of all stakeholders the roadmap towards an operational NSR will be realized. That roadmap will guide us from an innovation towards a registry of sensors that will scale to a national level. A true National Sensor Registry.

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BIOGRAPHICAL NOTES

Magdalena Maja Grus
MSc Magdalena Maja Grus is a research and innovation consultant in The Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster). For the last years her passion and subject of study has been citizen's science and its applications for the governmental datasets. Magdalena studied Land Use Planning and Management at Warsaw University of Life Sciences and Social Spatial Analyses at Wageningen University in the Netherlands. After graduation Magdalena worked first for geo related company and since 2010 for the Dutch Kadaster. Magdalena has been involved in various citizen's science related projects such as assessment of the volunteered geographic information feedback system for the Dutch Topographical Key Register. The ongoing projects and research subjects are Digital Twin, Sensor Registry, data experience and national youth project to collect data and increase children's involvement in the society. Since 2019 is Magdalena a bord member of Geo-information Netherlands association and from 2021 a bord member of EduGis - the platform for geo-information technology in education.

Marc Julien van Andel
BSc in Engineering Marc van Andel is a solution architect and technical researcher in The Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster). With a background in Mechanical Engineering Marc has been developing software for many years. Besides actual software development Marc's interests always covered architecture, structures and patterns in technical layers as well as people, teams and society. Past evolutions and disruptions were always a combination of needs and developments in society combined with technological trends and possibilities. For the last years Marc has been part of the Emerging Technology

Centre of Kadaster researching and experimenting with new technology in the quest what technology might bring to Kadaster and the Dutch government and how. By doing so Marc has laid the base architecture for the National Sensor Registry in a non-general known and used approach and technology.

Ronald Bokhove
BSc in Engineering Ronald Bokhove is a research and innovation consultant in The Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster). Ronald studied Cartography at the Technical High School in Utrecht and worked for almost 30 years for local governments and partnerships, where he specialized in exchanging geographical data. Besides that he developed courses and taught officials especially in managing the basic registration addresses and buildings (BAG). Ronald was also editor at the magazine Geo-Info, where he still contributes with discussing atlases and maps. He is highly interested in the development of the Key Registers.

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