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BUSINESS IMPACT ASSESSMENT OF SELF-GROWING ENERGY EFFICIENT SYSTEMS

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Abstract

This paper investigates the business impact of two novel mechanisms that increase the energy efficiency of networks, i.e. sensor network decentralisation and system idle time estimation, which have been developed in the CONSERN project. The analysis consists of two distinct but interrelated phases, the objective of which is to combine a techno-economic analysis of actual gains as contained within the technical KPIs of optimisation techniques, with a strategic analysis of factors promoting or hindering the actual introduction of these mechanisms within mobile business ecosystems. In the first phase, the technical gains of the two mechanisms are translated into an estimation of Operational Expenditure (OPEX) savings for a number of typical configurations. Subsequently, a business impact assessment is performed, in which two commercial deployment modes – an operator based and operator independent mode – are outlined. After having drawn up the business ecosystem for these two deployment models, a number of business opportunities and challenges for the two mechanisms in the different deployment modes are identified using the business model framework developed by Ballon, and a scorecard is used to weigh the importance of the various business model parameters against each other. The paper concludes with some recommendations and steps to mitigate disjunctions and improve synergies between the key stakeholders, constituting a sustainable business ecosystem.

Keywords: Business Models, Impact Assessment, Future Internet, Energy Efficiency, CONSERN.

1 Introduction

Energy aware technologies have already found their way into networking products and offerings of several device manufacturers and network operators. Mechanisms increasing the energy efficiency of network elements are not only beneficial from an environmental sustainability perspective, they may also lead to significant economic gains, especially in times of increasing energy cost and in sectors such as ICT where energy constitutes a significant factor in overall Operational Expenditure (OPEX). However, OPEX gains for these mechanisms can only really be obtained if a viable business model can be found through which they can be introduced. As we shall explain in this paper, the viability of such a business model, while of course also dependent on a sound cost and revenue structure, should be assessed as the interplay between a much wider array of control and value parameters, including the value network, functional architecture and value proposition.

This paper uses both techno-economic and strategic perspectives to assess the business impact of two such mechanisms, i.e. sensor network decentralisation and system idle time estimation, which have been developed in the EU FP7 ICT project CONSERN (EC, 2010). The project aims at developing a novel paradigm for dedicated, purpose-driven small-scale wireless networks with a special focus on energy-aware self-growing systems that promises improvements in terms of operational cost, product reliability, sustainability, and increased lifetime of wireless elements. With this objective, a number of interworking mechanisms have been developed, focusing on different mobile network elements ranging from macro and femto base stations to local gateways, routers, terminals and wireless sensors. While the former elements are typically already integrated into existing mobile network topologies, the rapid rise of M2M communications (projected 22-fold increase in traffic between 2011 and 2016 – Cisco, 2012), the specific characteristics of Wireless Sensor Networks (WSNs) like large-scale distribution of nodes, traffic profile etc., and the need for reliable mobile backhaul connectivity for these networks compels the Mobile Network Operators not only to increasingly develop service offerings aimed at providing ubiquitous and reliable connections to such networks, but could also use their experience and existing infrastructure to start operating such WSNs on behalf of their customers as a complementary business activity. Especially if such WSNs are deployed and managed across different customers, significant economies of scale could be reached. For this reason, both a WSN and a mobile system level mechanism have been selected for analysis in this paper, and both are studied from the perspective of potential inclusion into the Mobile ecosystem.

Section 2 of this paper outlines the general networking environment as considered in CONSERN, while Section 3 introduces the methodological framework for performing the business impact assessment. This framework consists of two components. First, a techno-economic analysis is performed, in which the technical gains of the two mechanisms are translated into an estimation of Operational Expenditure (OPEX) savings for a number of typical configurations. Secondly, the a business model framework (Ballon 2007) is introduced, which frames business models as inter-stakeholder configurations of control and value parameters, and represents a structured way to critically assess the design choices involved in constructing feasible and viable business models for both communications networks and services. For the purpose of this analysis, the generic business parameters of the framework are translated into more concrete business issues. Two distinct business models are constructed through which the mechanisms under study may be deployed. The crucial distinction between these two business archetypes is the business role taking up responsibility for deploying and operating the CONSERN optimised network elements: the first model is an “off the shelf” (Operator Independent) business model for these technologies, while the second one is an Operator Centric business model.

With these components in place, the dual analysis of techno-economic and strategic benefits and drawbacks of the two CONSERN mechanisms can be done in Sections 4 and 5. Space limitations in this paper, and the fact that its research objectives are decidedly non-technical, make that only a very concise description of the mechanisms can be given in Section 4. For more technical information, we may refer to CONSERN (2011a, 2011b). Section 4 separately evaluates the techno-economic impact and strategic business model issues for the two mechanisms while Section 5 takes the two mechanisms together and cross-compares their business impacts for an Operator Independent versus Operator Centric deployment mode. A scorecard method is used to visualise these findings. Section 6 makes some conclusions and recommendations for further work.

2 Technical Overview of Self Growing Energy Efficient Systems

Self-growing Energy Efficient Systems form a novel paradigm introduced by the EC FP7 Project CONSERN aiming at tightly couple the Project's two main research axes, Self-Growing and Energy Efficiency. Self-growing signifies the ability of a network to evolve and accommodate, in an automated yet controllable way, new devices, novel technologies and networks in order to serve a different purpose or improve performance efficiency. Self-growing capabilities can have a direct impact on energy optimization as a system featuring self-growing capabilities at network or network node level should reserve spare energy or fallback energy strategies to handle the communication overhead of related reconfigurations. Self-growing capabilities should also consider the remaining energy of nodes and their priorities of processing certain tasks to decide whether a node can take over additional roles or tasks along self-growing lifecycle.

Energy efficient solutions create an attractive business case by offering significant benefits in terms of operational cost, long-term product reliability, sustainability, and increased lifetime of wireless elements. In the context of CONSERN project both cooperative and non-cooperative energy optimisations are being developed and evaluated at networking and system level or terminal level including (i) energy aware techniques that can be used at run-time and (ii) those that can be applied during the network design phase. This paper presents two technical solutions for energy optimisations on network and terminal level together with corresponding business impact assessment.

2.1 CONSERN Networking Environment

CONSERN facilitates the Self-Growing capability of a small-scale wireless network through autonomic and co-operative approaches that minimize human intervention while catering for energy usage optimization at system, network, network node and user equipment level. The corresponding overall networking environment has been identified (in *Figure **1***) as multi-domain, heterogeneous, dense home/office environment where different networking services and capabilities are being provided by different providers and infrastructures.

In essence, CONSERN provides new processing and communication schemes within the presented networking environment thus enabling interworking of different network devices featuring the following functionality: 1) Knowledge Base for network state, events, and actions, 2) Decision Making 3) Self-growing 4) Cooperation 5) Autonomic Control 6) Monitoring, 7) Execution and 8) Translation of abstract configuration commands into vendor/hardware specific configurations.

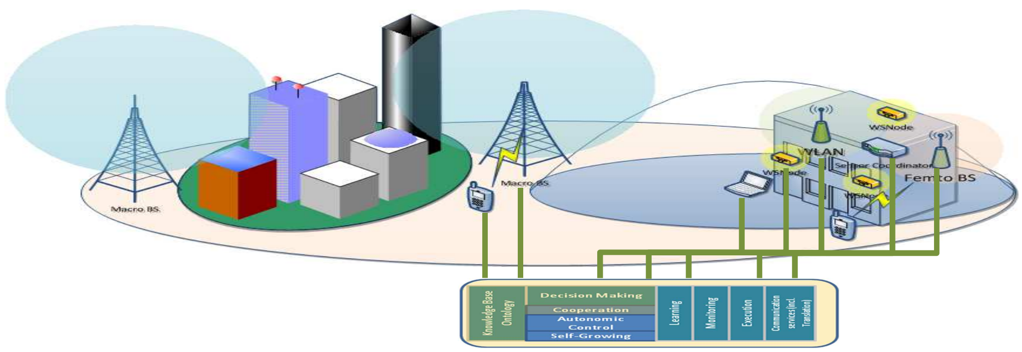

Figure 1. CONSERN's networking environment realising CONSERN functionality.

2.2 Energy Optimisations at System Level

CONSERN encompasses a set of solutions and respective mechanisms addressing key goals and objectives for self-growing energy efficient networking in both autonomic and cooperative fashion. Energy optimisations at system level have been developed on theoretical modelling and simulation basis or on a real test bed featuring WSN nodes. Specifically, among others the following mechanisms and studies have been developed and evaluated:

- A Sensor Network Decentralization mechanism,
- System Idle Time Estimation techniques used to explore a couple of different power level selection strategies,

Section 4 presents the two mechanisms in more detail and provide technical basis for conducting business impact assessment.

3 Methodological framework

The two mechanisms described (Section 4) will be subjected to both a techno-economic and a strategic business impact assessment, the latter of which first uses a business model framework outlined by Ballon (2009), and subsequently outlines two deployment modes – an "off the shelf" (Operator Independent) an Operator Centric business model – in order to cross-compare the identified business impacts for the two deployment modes in a scorecard.

For the techno-economic analysis, the technical performance metrics of the two mechanisms under study were the starting point. These were extensively discussed with the developers, in order to 1) understand the technical gains in general (e.g. throughput, transmissions etc.), to 2) derive energy efficiency gains from these metrics (e.g. throughput gains resulting in reduced transmission energy required) and 3) to understand the envisaged network topology in order to understand typical OPEX structures in a business-as-usual scenario. Based on this, the impact of the mechanisms on OPEX was calculated. As will be shown, the OPEX gains identified are often dependent on the specific roll-out model of the mechanism envisaged. This shows the necessity to complement this approach with a more strategic, business model oriented analysis. The method for this analysis, which formed the second phase of the research, is explained in some more detail below.

3.1 Framework for Business Impact Assessment

Business Modelling is a growing field of investigation and it is therefore important to approach it in a structured way. Often cited works Business modelling are Osterwalder (2004) and Osterwalder and Pigneur (2002, 2010), from which the much-used Business modelling canvas has been created. A limitation of their work and of most related work on business modelling is that it is mainly situated within the boundaries and/or perspective of one organization. It is therefore most suited for aiding individual companies' strategic decision making processes, and less so for supporting and guiding collective innovation processes. A second stream of literature, which remediates somewhat this focus on the single organisation, is based on Chesbrough's Open Innovation (2003) and Open Business Model (2006) concepts. This concept is useful since it focuses on collaborations and value sharing between commercial actors. The Open Innovation and Open Business model concepts, however, are focused first and foremost on the sharing and licensing of intellectual property (IP), and do not cover a range of additional issues crucial to systemic innovation, including customer ownership, interoperability strategies, and revenue sharing arrangements.

In order to fill the above gaps, it is necessary to consider a third stream of literature that attempts to provide a more coherent treatment of the most relevant business model parameters (beyond the exchange of IP), while focusing mainly on the relationships between stakeholders involved in collective innovation (rather than limiting the analysis to the decision-making within a single firm).

Ballon (2007), proposes a business model ontology combining collective business, technical and financial architectures, with the resulting value propositions, and framing these as configurations of control and value parameters. The underlying assertion is that, for a business model to be viable, a "strategic fit" between stakeholders is required on the different design choices that are possible within these parameters. The framework was originally tested with both access and service platforms for mobile telecommunications systems, and has since been used to assess business models for a number of ICT innovations including SaaS and PaaS platforms, Cognitive and autonomic Wireless Systems, ITS services etc. *Table **1*** shows the ontology originally developed.

Table 1. Generic business model framework

Control Parameters		**Value parameters**	
Value Network	**Functional Architecture**	**Financial Model**	**Value Proposition**
A.1. Combination of assets	B..1. Modularity	C.1. Cost (sharing) model	D.1. Positioning
A.2 Vertical integration	B.2. Distribution of intelligence	C.2. Revenue model	D.2. User involvement
A.3 Customer ownership	B.3. Interoperability	C.3. Revenue sharing model	D.3. Intended value

Given the specificity of the technology under evaluation, we adapted the business model parameters from (Ballon, 2007) in order to match the requirements and constraints posed by energy aware business ecosystems. The table below explains each BM parameter in detail:

Table 2. Business model parameters for impact assessment

Parameter	Definition
Key Value Proposition	The basic attributes that the product or service possesses which constitute the intended value to be delivered to the customer
Dependencies and Control	Refers to the distribution of processing power, control and management of functionality across the system in order to deliver a specific application or service
Partnerships	Strategic combination of resources that are available and useful in any activities a stakeholder undertakes in pursuing its goals
Know-how	Points to the possession of critical skills and resources in order to deliver the key value proposition of the service or product
Product	Refers to the complementarity and substitutability between products and services
Legacy	Related with the ability of systems to directly exchange information and services with other systems, and to the interworking of services and products originating from different sources
Deployment	Refers to issues and attributes attached to basic deployments and operations of such systems
Customer	Differentiates the type of customer base that interacts in the ecosystem

Using each business model parameter in *Table **2**,* an in depth mechanism-specific impact assessment exercise is performed to qualitatively estimate the intensity of impacts originating from the trade-offs and benefits of engaging in the two business models. In order to further strengthen our analysis, we crosschecked and verified our findings through multiple rounds of feedbacks and validations with stakeholders active in the CONSERN ecosystem.

3.2 Business Ecosystem Design

Currently, wireless network development is driven by horizontal mass-markets ("one size fits all"), whereas vertical markets and niche applications calls for (costly) dedicated configurations or developments. The choice of business models for such systems is greatly dependent on the preferences and priorities of business stakeholders involved. These business models can further be used to highlight the value proposition inherent in the systems operating under various value and control constraints. The two key variations in business model are: (1) Operator Centric Business Model (OC-BM) and (2) Operator Independent Business Model (OI-BM).

Figure 2 combines the two business model configurations where either a Network Operator or a Facility Owner is solely responsible for building and operating a CONSERN-like ecosystem. Operator Centric Business Model (on left in green) is a "business as usual" scenario where Network Operators choose to deploy the networking infrastructure and possess relevant skills to operate them. In terms of revenue flow and control, the Network Operator being the focal actor intermediates the flow of revenue and services i.e., the Network Operator chooses to internally negotiate and pay the Device Manufacturers and Service Providers for the purchase of equipment and services respectively.

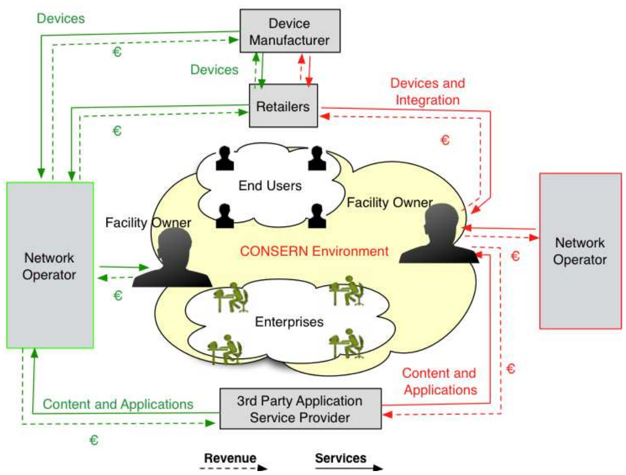

Figure 2. Operator Centric (left-green) and Operator Independent (right-red) business models

On the contrary, the Operator Independent model represents the case where the Facility Owner (like airports, hotels etc.) chooses to build and operate the CONSERN ecosystem. The Facility Owner makes use of "off-the-shelf" products and deploys them independently or with help of 3rd Party Integrators. In place of an incumbent operator, the Facility Owner interacts directly with Device Manufacturers (through Retailers) and the Service Providers for provisioning components and services. The key motivation for developing an alternative Operator Independent business model is the fact that it explicitly captures the underlying need to deliver significant and specific impact on end users that do not have the resources to set up complex networks and which are especially benefiting from power efficient, easily scalable solutions.

4 IMPACT ANALYSIS

4.1 Sensor Network Decentralization Mechanism

The sensor network decentralization mechanism investigates the performance of the network as the size of the network grows. Here we use a scenario where, initially, the system is operating in a centralised mode and consists of a gateway device along with a small number of battery-powered sensor devices that report directly to the gateway. As more sensors are added to the network, some change into aggregator mode and allow other sensors to report their measurements to them directly. In fully decentralised mode only a few aggregators report to the gateway, while most are aggregating and forwarding samples from other aggregators. A report to the central gateway is referred to as a global transmission, while a report to a nearby aggregator is termed as local transmission. Due to increased transmission power a global transmission uses more energy than a local one. *Figure 3* shows a network in centralised mode [left] and a larger network in decentralised mode [right]. The sensor devices run processes that obtain sensor samples and can aggregate and transmit aggregated values. A gateway central node (in blue) controls the collection and reporting of the data.

As the system grows, for efficiency and energy consumption reasons the system moves from a centralized polled system into a more decentralized one where collected data is summarized at intermediate points, and control is delegated to selected devices. Thus the use of the decentralised mode of this system can act as a power saving mechanism, under certain conditions that depend on the size of the network and how densely the sensors are distributed. Impacts of these transitions from centralized to decentralized modes have been explored using measurements and simulation results.

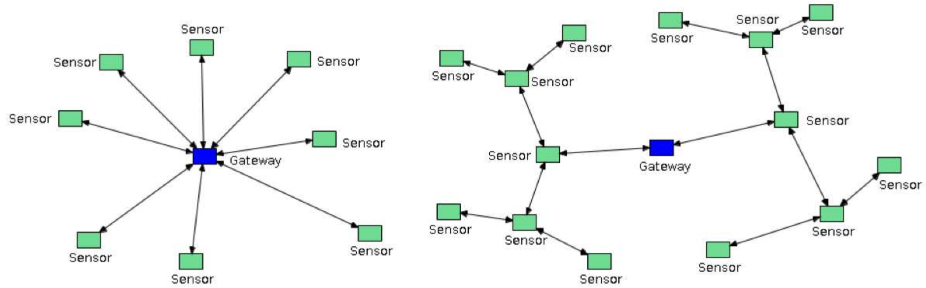

Figure 3. *Centralized [left] and decentralized [right] modes of operation*

4.1.1 Impact on Transmission and Energy Overhead

This mechanism achieves substantial reduction in high-energy transmissions to the central gateway, which in turn lowers the energy footprint of the sensor network, under certain circumstances. The total power consumption for such a system is dependent on the number of sensors and the relative power consumption of each global and local transmission through the system. For varied range of power figure ratios from 1.6 to 3.0 (energy consumption of a global transmission divided by the energy cost of a local transmission), *Figure **4*** projects the estimated savings w.r.t the increase in network size. The parts of the curves above the reference line (in red) are where the decentralized mode has a higher energy cost than the centralized one, and below those where decentralization has energy benefit. It is important to realise that the mechanism is adaptive and hence it switches between the modes as the network grows or shrinks, to the mode with the lowest power cost.

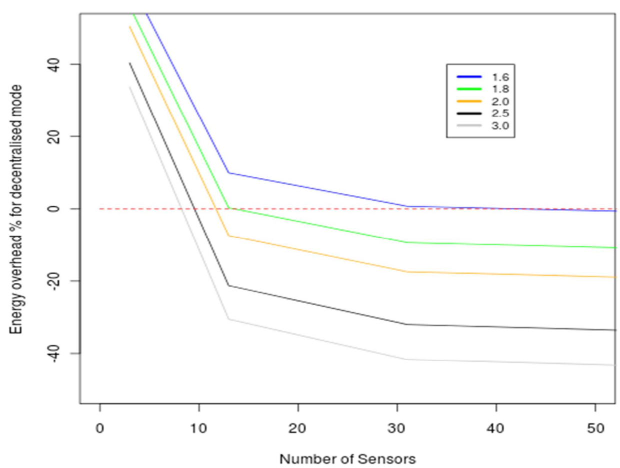

Figure 4. *Impact on transmission and energy overhead*

4.1.2 Impact on OPEX

Since the sensors are powered by batteries, the cost savings of lower power consuption due to network decentralization can be found on two levels: (1) reduced battery costs and (2) reduced human intervention and replacement costs. In order to translate the average power savings of the network into average economic impact, we first establish the baseline power consumption of a centralized architecture and then cross compare the gains achieved by enabling network decentralization for the same network setup. Using our experimental setup we know that each node is powered by one standard AA battery (i.e., 2.6 Wh for every 6 months per sensor node), and price of each Lithium ion AA battery is about 2€. With an estimated energy saving of 44% from overhead graph in *Figure **4*** and an average lifetime of 5 years we assess the impact of network decentralization on OPEX when scaled from 10 nodes to 400 nodes (8 clusters each of 50 nodes). Therefore:

Estimated Consumption per node in 6 months: 2.6 Wh

Estimated Consumption per cluster in 5 years: $2.6\times 2\times 5\times 50$ Wh

$$Total\ Cost\ Savings = (Cost\ per\ AA\ battery)\times(Mechanism\ Gains)\times\left(\frac{Estimated\ Consumption}{Power\ per\ AA\ battery}\right)$$

$$Total\ Cost\ Savings\ (OpEx1) = (2)\times(0.44)\times\left(\frac{2.6\times 2\times 5\times 50}{2.6}\right) = 440€$$

An increase in battery life also implies a decrease in frequency of replacements and hence additional economic gains (OPEX2) due to reduced human intervention are to be considered. Usually a team of two ICT-skilled technicians take a full day to change all the batteries of a network equipped with 50 sensor nodes. Therefore, *Table **3*** highlights the results in terms of cost benefits (OPEX1) and additional benefits (OPEX2) accrued by the sensor decentralization mechanism.

Table 3. Impact on OPEX due to lower batteries cost and reduced human intervention

Size (N)	OPEX1 (€)	Batteries	Mandays needed for replacement	OPEX2 (€)	(OPEX1+OPEX2) (€)
50	440	220	8.8	1760	2200
100	880	440	17.6	3520	4400
200	1760	880	35.2	7040	8800
400	3520	1760	70.4	14080	17600

Note: OPEX2= (mandays) x 200 € / manday

It can be seen that gains are more pronounced with increasing scale in the network, therefore stakeholders with large customer base or facilities like hotels, airports etc., are best placed in the value network to exploit the gains produced by the mechanism.

4.1.3 Impact on Business Model Parameters

As mentioned in the introduction, there are important impacts other than cost and OPEX related which are elaborated in *Table **3***. Using each business model parameter in *Table* **2,** an in depth mechanism-specific impact assessment exercise was performed to qualitatively estimate the intensity of impacts, highlighting positive impacts in green and problems in red. Next to this assessment, the table highlights the trade-offs and benefits of engaging in the two business models (OC-BM and OI-BM), a scorecard is constructed, where positive or negative impacts from both the mechanisms are weighed relatively as "Low" (relatively low relevancy) to "High" (relatively high relevancy) in the configuration of the business model parameter and related trade-offs. Some of the business model parameters are either irrelevant or are inaccessible (due to technical constraints or design issues) for a given business model configuration, hence resulting impacts are denoted by "No" - either non assessable, or non relevant. The implications of this business analysis are elaborated in Section 5.

Table 4. Business model impact for Network Decentralization mechanism

	Business model impacts	OC-BM		OI-BM	
		+	-	+	-
Key Value Proposition	For an increase in network size from 10 to 50, energy savings of 40% can be achieved. However, scaling of networks nodes will be more common in case of large-scale CONSERN deployments realized by the Network Operators (when compared to the off the shelf devices). Operators through this mechanism can foresee further increase in their customer base. However, this increase will further lead to increased Network Management tasks and hence OPEX costs.	High	Low	Low	Low

Dependencies	Mechanism emphasizes on distribution of intelligence amongst the nodes. Though it lowers the load from the gateway, but if the aggregating node (secondary gateway) fails, it risks interrupting the transmissions originating from the rest of the nodes.	Low	Low	Low	Low
P/ship	The switch between centralized and decentralized mode is fully automated, hence both BMs can prove effective in terms of network operations and maintenance.	Low	No	Low	No
Know-how	Due to adaptive switch between centralized and decentralized mode the end customers are rarely (or never) exposed to the operational intricacies. Operators are required to possess the knowledge of designing and operating such network. There are additional gains in OI-BM if the building owner has multiple properties where CONSERN can be deployed. On the one hand, the Building Owner with gain from multiple deployments, but he also has to develop the know-how.	Low	Low	Medium	Low
Product Bundling	Success highly depends on standardization of CONSERN functionalities. Higher chances of interoperability if an Operator is employed whereas for "do it yourself" model, unbundled products can have compatibility and interoperability issues.	Low	Low	No	Medium
Legacy	Mechanism is not interoperable with other legacy devices, extra CAPEX is required to deploy CONSERN enabled devices.	No	Low	No	Low
Deployment	Assuming tenants will refrain from long-term investments in infrastructure, the Facility Owner has to absorb the upfront costs of CONSERN infrastructure at the same time benefits are multiplied when the Operator installs CONSERN system over multiple tenants over the network lifecycle. In an OC-BM the Operator has to invest in place of the Facility Owner and increase the monthly subscription rates.	Low	Low	Low	Low
Customer Segments	With increasing network size like Campus Environment, etc., Operators can expand CONSERN applications into greater customer base. However, home/office spaces where the network size and node density is usually limited, switching to decentralized modes can be inhibited in case of failure to reach the threshold limits, hence economic gains will further be limited.	Low	High	Low	High

Note: Positive impacts are shown in green while negative or problematic ones are in red

4.2 System Idle-Time Estimation Mechanism

The estimation of idle time of a node or a device is considered as a key enabler for achieving high energy gains in future energy-aware systems; if it can be accurately estimated, the system can enter low energy mode. This mechanism aims at minimizing the sensing trials thus minimizing energy spent for sensing while maintaining the highest degree of event tracking. As has been shown by traffic analysis (Altman, 2005; Misra, 1999), in high dense node environment events occur in a batch mode, meaning that an event is followed – with high probability - by a number of other events. Based on this assumption, an event-driven algorithmic solution (based on a stochastic model) has been developed with a twofold aim; the maximization of the successful identification of events and simultaneously minimization of energy consumption. Upon implementation, each network node can track as more events as possible (preferably all) and the overall network consumes as less energy as possible by minimizing the sensing trials.

4.2.1 Impact on OPEX due to Energy Savings

The simulations show that the energy for executing the proposed scheme is significantly less compared to that of the base case (without CONSERN implementation); therefore the energy gains derived from the "intelligent" derivation of the sleep time may vary from 39% (worst case) to 56% (best case) setup (*Table 5*). Next, we assess the network-wide impact on businesses especially network operators deploying entire product lines of networking devices (wireless access points, routers etc.) for their subscriber base. The values in *Table **5*** are platform-specific (Intel x86) and might yield different results depending on which actual networking elements execute the algorithms.

Without implementation, the energy consumption of the test x86 platform is measured around 10.78 Joules (base case). Assuming a lifecycle of 5 years and 10,000 home/office deployments with at least 5 interconnected devices, the total number of Network Elements is estimated around 50,000. Cost of kWh in Belgium is 22€ cents however for some member states like Greece, this number can fall as low as 13€ cents. (EU Energy, 2012). Therefore using the Energy Cost expression below we estimate an average financial gain of 46% (relative to the base case) with 5% standard deviation.

$$Energy\ Cost = (Cost\ per\ kWh) \times (Number\ of\ Devices) \times \left(\frac{\left(\frac{Absolute\ Power\ Consumption}{Device} \times Time(in\ hours) \right)}{1000} \right)$$

Table 5. System Idle-Time Estimation mechanism impact on power consumption and OPEX

Set up	Absolute Consumption (J)	Savings w.r.t. Base Case (%)	Energy Costs (in €)	Cost Savings Relative to the Trivial Case (in €)
Base case (w/o CONSERN)	10.78	-	5193804	-
Worst case (w/ CONSERN)	4.2	39	2023560	3170244
Best case (w/ CONSERN)	6.03	56	2905254	2288550
Avg. case (w/ CONSERN)	5.07	47	2442726	2751078

4.2.2 Impact on Business Model Parameters

Similar to Section 4.1.3 a business impact assessment was performed, the results of which will be further discussed below:

Table 6. Business model impact assessment for System-Idle Time Estimation mechanism

	OC-BM and OI-BM Impacts	OC-BM		OI-BM	
		+	-	+	-
Value Prop	Mechanism can reduce the net consumption up to 56%, further contributing to the overall energy savings. Primarily aimed Operatos the gains in OPEX due to the intelligent sleep derivation can save up to 3.2M € over a time period of 10 years.	Medium	No	Low	No
P/ship	Mechanism saves costs and increases the sleep time of a network, if network and service continuity and savings are deemed feasible, both an BMs can prove effective.	Low	No	Low	No
Know-How	This mechanism allows the network devices to intelligently derive sleep times depending on the trigger events. The end customers are rarely (or never) exposed to the operational intricacies.	Low	No	Low	No
Product Bundling	Higher gains can be achieved due to economies of scale and cost leadership if deployed in large numbers (OC-BM). Also due to standardization reasons the gains will be more prominent in case an Operator is employed to deploy the devices equipped with this mechanism.	Medium	No	Low	No
Legacy	Interoperability with the legacy device will be an issue if an industry wide effort for standardization is not in place. However with Operators deploying the CONSERN enabled devices can help minimize the mismatch and other interoperability issues with already existing legacy devices.	Low	Low	No	Low
Deployment	Apart from other operational responsibilities, the mechanism is automatically updated (SW) irrespective of the business model under consideration.	Low	No	Low	No
Customer Segments	Various customer segments could be served in parallel either by the Operator or the Building Owner himself. However, when considering SOHO Environments due the small network size and distributed nature of deployments, gains achieved due to the mechanism are further diluted; and the OI-BM yields limited economic gains.	Low	No	Low	High

5 Cross-Comparison and Operationalization of Impacts

The following section synthesizes and cross compares each mechanism-specific business impact captured in *Table* ***4*** and *Table* ***6***. Highlighting the benefits and obstacles for both mechanisms of engaging in the two, a scorecard is constructed (*Figure* ***5***) where the right hand side of the figure included an overall assessment for the two mechanisms taken together.

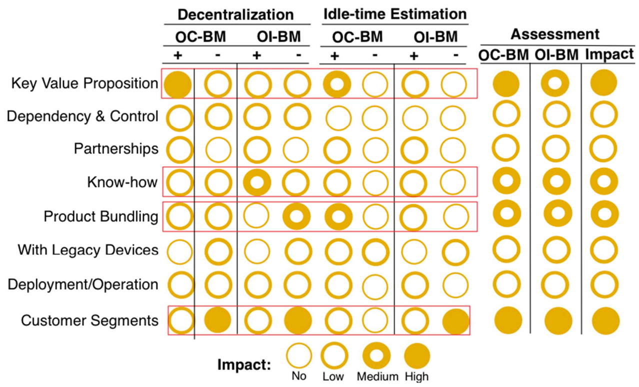

Figure 5. Business impact scorecard for the two mechanisms

The assessment shows there are four business model parameters, (1) the value proposition, (2) know-how, (3) bundling and (4) customer segments, where impacts are critical. *Table **7*** elaborates these critical business model parameters evaluates the key concerns and implications from a focal stakeholder point of view.

Table 7. Critical parameter specific implications: OC-BM vs OI-BM

Key Value Proposition		
Impact	High	Energy savings requires inter-domain networks to be scalable and operable in tandem. This is possible only when Facility Owners and Operators reach common grounds. Such agreements are rare today.
OC-BM	High	Key incentives for inter-operator agreements presuppose that the benefits from venturing into CONSERN would be clear to the Network Operator.
OI-BM	Medium	Facility Owners should discuss with operators before moving forward with deployment, as there might be interference and incompatibility issues for other co-existing networks.
Know-How		
Impact	Medium	Operators and Facility Owners need to develop expertise to operate and deploy CONSERN systems
OC-BM	Medium	For Network Operators to develop the relevant skills and know-how, value proposition of CONSERN should be aligned with long-term business model of the operator.
OI-BM	Medium	3rd party provider can deploy and operate the CONSERN systems. For Facility Owners with limited experience of ICT, “off the shelf” devices require plug and play like functionalities; else it may be challenging to develop specific skills in limited time.
Product Bundling		
Impact	Medium	Along with customers, other stakeholders in the value network must be inclined towards integration and adaptation of new/energy aware technologies and services. This is only possible when proper standardization mechanism is put in place.
OC-BM	Medium	A greater push for standardization is required. Network Operators and Device Manufacturers are best placed to pave the way for standardization.
OI-BM	Medium	Facility Owners deploying unbundled devices from “off the shelf” retailers etc. risks facing incompatibility issues with existing networks and devices.
Customer Segments		
Impact	High	Mechanisms are highly sensitive to scaling, not only the performance also cost and operational benefits are directly correlated to the ability of each mechanism to scale.
OC-BM	High	Deployments where gains achieved due to the mechanism are diluted due to the scalability, operators are better placed to absorb the upfront costs and generate benefits due to economies of scale and control of the ecosystem.
OI-BM	High	Large independent stakeholders like Enterprises, Airports, and Hotels etc., can operate by outsourcing critical tasks to 3rd party integrator. Thereby generating benefits similar to an operator (economies of scale and control over the ecosystem).

In conclusion, due to issues of know-how, scaling and compatibility, an operator-centric business model appears to be somewhat better in aligning value creation and control parameters in the introduction of CONSERN mechanism. In which case these issues needs to be addressed in order to create a commercially sustainable business ecosystem.

6 Conclusions and Future Work

This paper evaluated two energy efficient self-growing mechanisms currently being researched and developed in the FP7 Project CONSERN. A techno-economic analysis of the two mechanisms demonstrated both as promising paths towards energy-efficiency. Due to the additive nature of their impacts, the overall energy and cost savings increase with network size.

In a second step, we used business models approach as a structured way to critically assess the design choices involved in constructing feasible and viable business models for both mechanisms and for two possible business models (Operator Centric or Operator Independent. Four critical business model parameters – Value Proposition, Know-How, Product Bundling and Customer Segments were identified and we explored further actionable recommendations and mitigation steps that key stakeholders like the Network Operator and the Facility Owner can take in order to co-create a sustainable business ecosystem.

Our recommendations include the need for inter-operator agreements, the push for standardisation, competence build-up among operators and/or the development of standardised "off the shelf" solutions and the need for scaling the implementation of the solutions. Among many avenues fruitful for further research, the most urgent one would be to analyse similar mechanisms currently being researched using our proposed framework.

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