# Planning for 5G: a problem structuring approach for survival in the telecoms industry

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*Abstract* – This paper examines the application of systemic problem structuring methods to the development of research strategy in response to the challenges of 5G. The paper proposes a methodology for strategic decision making. The key stakeholders, objectives, technologies and boundaries from existing literature are identified and problem structuring based on hierarchical process modelling is used to explore the dependency of certain features of 5G on specific technologies, giving an indication of the importance of certain technologies over others and thus insight into where to place research effort. The hard technical challenges of 5G are discussed and equally the importance of the soft social and business challenges explored. For context, we explain how 5G will provide a platform for innovations and discuss how new and existing businesses may use this to their advantage. Problem structuring is used to explore how the challenges and opportunities of future wireless systems are related to the process of developing new business models.

*Index Terms*—5G; Problem Structuring Method (PSM); Systems Engineering; Business Model

## I. Introduction

THE Telecommunication industry has been growing at an unprecedented rate over the last three decades, during which the world has seen the development of four generations of cellular technologies. While the industry is mainly focused on the deployment of the fourth generation systems at present, global research and development efforts (i.e. a number of projects in Europe, US and Asia) are already underway to develop the fifth generation (5G) telecommunication system (Felita and Suryanegara, 2013). Further, the International Telecom Union (ITU) has also started a standardization effort which works towards specifying the overall framework and objective of the future development of 5G discussing aspects such as technology trends and the technical feasibility of new frequency bands.

It is acknowledged widely that the underlying difference between 5G and previous generations of mobile technology is that it will consist of more than just one radio access technology. The trend of using multiple radio access technologies for providing network services is already well established and practiced widely by operators. For instance, many operators own WiFi hotspot services in addition to their cellular networks. This architecture is well supported by wide availability of smart mobile devices

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equipped with multiple radios such as cellular (3G/4G), WiFi, and Bluetooth. This observation is complemented by the description of the technology as highly integrative between the new 5G air interface with LTE and WiFi (Andrews et al., 2014). It is suggested that 5G wireless communication systems will require a mix of new system concepts to boost their spectral and energy efficiency (Ekram Hossain, Mehdi Rasti, Hina Tabassum, 2014).

In line with the above observations and predictions, this paper hypothesizes that the 5G communication system will be far more complex than any of the previous generations, which mostly use homogeneous technologies with vertically integrated market structures. In contrast, the 5G system will be a complex socio-economic-technical system which will integrate different communications sub-systems that use one or few specific technology solutions and network architectures into a single larger system architecture (Maier and Rechtin, 2009), facilitating multiple service operators and a range of applications to co-exist, enabling innovative market opportunities.

The paper explores the question of how to develop strategy for research investment in the complex development space of 5G technologies, and proposes a methodology for doing this. The approach used is based on the use of Problem Structuring Methods (PSMs) and focuses on developing a clearer understanding of the development landscape of the telecoms industry for informed decision making. The paper takes the perspective that the historical development of the industry will also provide some insight into the shape of its future. The influence of key state of the art technologies and major projects are considered.

The paper is organized as follows. In section II we develop a landscape of the telecoms industry by understanding its historical development, examining the proposed development towards 5G and reviewing the industry 'state of the art'. In section III we discuss problem structuring and modelling techniques and their application to our problem. Further, we apply stakeholder mapping and Hierarchical Process Modeling (HPM). In section IV we discuss the implications of our problem structuring. In section V we perform a second iteration of our methodology incorporating our findings so far. In section VI we discuss our findings and methodology and section VII we give conclusions.

## II. The Context of 5G Development

### A. *Understanding the Historical Context*

In trying to understand how the telecoms industry will progress, it is sensible to look at how it has evolved up to now. Reviewing the history aims to provide context and begins to develop a conceptual landscape of the telecoms industry. From a look at the historical development of the telecoms industry some observations are made.

Figure 1 – Historical timeline of the mobile telecoms industry highlighting some key moments in its development. Key terms: CDMA -Code Division Multiple Access, AMPS - Advanced Mobile Phone System, GPRS – General Packet Reconstruction System, UMTS – Universal Mobile Telecommunications System, 3GPP – 3rd Generation Project Partnership, GSM - Global System for Mobile Communications, LTE – Long Term Evolution. The information for the timeline was adapted from (UMTSWORLD, 2006) and (Wirelesshistoryfoundation, 2015).

The technology of the telecoms industry is always chasing rising data demand. Data demand has increased faster than technology can keep up. Development of new technologies seems to be accelerating. The time from a standard being formed to a technology being realized has decreased over the time of the industry. This is presumably due to the increased size of the industry and the associated economy attracting an increased number of participating research and development organizations along with more established R&D techniques. Notably, the rate of development of physical layer technologies has slowed in the latter period of this timeline, primarily due to link-level throughputs approaching Shannon's limit (Rappaport, 1996), whereas improvements to MAC layer technologies have accelerated. Heterogeneity has been a developing trend throughout the telecoms timeline and so the assumption that this trend will continue into 5G seems sensible (Andrews et al., 2014).

Innovation has been key to success in the telecoms industry. Staying ahead of the technology curve (Asthana, 1995) and reaching the market early with new technologies have seen benefit in attracting new customers. Ambidextrous organizations (O'Reilly, Harreld and Tushman, 2009; O'Reilly and Tushman, 2011) able to explore future options, build resources and manage ongoing R&D and grow the profitability of the ongoing business have become significant in the industry over its development such as Samsung. Innovation alone has not been sufficient to stay at the top. Former industry leader Nortel Networks R&D labs produced the world's first entirely digital phone network and dominated the fibre-optic network in the early 2000s but due to lack of a clear strategy, descended into mediocrity (Sturgeon, 2012). In 2009 they filed for protection from creditors under bankruptcy. Motorola, a key innovator in the early years of telecoms, having stagnated in growth and witnessed a decline in market share was bought out by Google (Motorola, 2015; Google, 2014). Google was interested in acquiring the company's patent portfolio and increasing the popularity of their android operating system (Levy, 2013), they proceeded to sell-on the remaining aspects of the company.

Large organizations within the telecoms industry have often portrayed a monopoly mentality looking to dominate the industry by growing their assets. However in recent years this strategy has been disrupted by the emergence of OTT (Over the top) providers which have in many cases have become more profitable (Mahola and Erasmus, 2015).

### *B. Understanding Current Development Timeline to 5G*

Having reviewed the history we must now consider the current 'state of the art' in the Telecoms industry.

Figure 2 – Timeline to 5G. As proposed by International Telecoms Union (ITU) in blue and 3rd Generation Project Partnership (3GPP) in yellow.

Figure 2 shows a timeline to development of 5G as proposed by International Telecoms Union (ITU) in blue and 3rd Generation Project Partnership (3GPP) in yellow. These are two regulation bodies heavily influenced by many significant European projects already underway; these include TOUCAN (2015), 5G-XHaul (2014), MmMAGIC (2014), 5G-Now (2014) and The METIS 2020 Project (2015) and many others. These projects are focusing primarily on the architecture of 5G and are presently at the stage of defining the architectures requirements. Some of the technology drivers and business opportunities discussed in these projects are expanded in the following sections.

### *C. Understanding the Technical Drivers Context*

The 'Mobile and wireless communications Enablers for the Twenty-twenty Information Society' (METIS) identify some technical requirements envisaged for 5G (Osseiran et al., 2014). These are:

- "1000 times higher mobile data volume per area
- 10 to 100 times higher number of connected devices
- 10 to 100 times higher user data rate
- 10 times longer battery life for low-power massive machine communication (MMC)
- 5 times reduced end-to-end latency" (Osseiran et al., 2014)

Key drivers and technologies of 5G have been identified at a physical layer (PHY), radio resource management (RRM) techniques and medium access control (MAC) layer (Felita and Suryanegara, 2013; Andrews et al., 2014; Ekram Hossain, Mehdi Rasti, Hina Tabassum, 2014; Osseiran et al., 2014; Gohil, Modi and Patel, 2013). Drivers include the significant continuing increased data demand and increasing number of connected devices (the Internet of Things (IoT)). Further drivers include a demand for reduced latency, real time control, total coverage, improved quality of service (QoS), personalized service and continued service while in high density population areas or while travelling. Technologies include among others, extreme densification (small cells) and offloading to improve spectral efficiency; millimeter wave, multiple input multiple output (MIMO); orthogonal frequency division multiplexing (OFDM); software defined networks (SDN), network function virtualization (NFV); cloud/fog computing; open transport protocol layer; cognitive radio access technology (RAT) selection; device to device (D2D) communication and several others. Most technology candidates for 5G are aimed at the larger consumer market, however the scope of 5G may extend to cover other use cases including emergency situations such as natural disasters and the IoT related application such as driverless cars and e-health. (Evans, 2014) argues the importance of the role of satellites in 5G highlighting the improved coverage in rural areas, resilience and security they can provide in the event of a natural disaster, along with the locational benefit they can provide in the future of the Internet of Things and intelligent transport systems. The current challenge lies in integrating the existing satellite technologies into the 5G architecture. The papers form a consensus that 5G will be significantly more complex than any previous generation of mobile technology, and will only be successful in meeting the set objectives as a result of multiple technologies combining to form a highly heterogeneous system.

### *D. Understanding New Business Opportunities for 5G*

Driverless cars, e-health, and virtual reality are all presently exciting areas of research with high profile industry projects underway such as those by Google and Volvo (Google, 2015; Volvo, 2015). Other research grant-funded major projects include Venturer (Bristol-City-Council, 2014), bringing together research institutes and automotive industry expertise, and SPHERE (SPHERE, 2015) working with clinicians, engineers, designers and social care professionals. Proposed technologies in these areas rely on extremely high data rate transmission and other characteristics common of the proposed 5G network.

Using driverless cars as an example, one way of achieving this is using sensor and vision technology built into a normal car. The car could be released onto the road and observe traffic just as a human driver would. A further development to this model for driverless cars depicts a system whereby all traffic is constantly communicating with each other. Clever, centrally controlled routing algorithms automatically direct cars via different paths into a city center to reduce congestion. Cars travelling fast on open roads are able to communicate and drive very close together slipstreaming behind one another to make journeys more fuel efficient. At crossroads, cars approaching from all directions can communicate and calculate distances so precisely there will barely be a need to slow down; they will pass close to each other at speed. This kind of significantly more sophisticated autonomous transport requires high data rate transfer over a robust reliable network, which currently 4G does not provide and therefore could benefit from 5G. There are projects in existence such as investigating vehicle-to-vehicle and vehicle-to-infrastructure communication for infotainment and vehicle safety applications (Doufexi, 2015). The project considers TV whitespace and LTE at 800MHz and higher frequencies comparing rural and urban areas at different vehicle speeds as explained in (Goulianos et al., 2015).

Already many e-health devices are available on the market to monitor daily activity levels considering fitness and wellbeing applications. Some hospitals have adopted systems of discharging patients with devices that can be used to track their recovery. A reliable high speed 5G connection would allow for far more significant innovation in this area. For example the SPHERE project (SPHERE, 2015) envisages that patients could be released from the hospital and remotely monitored in real time by doctors. Through monitoring vital signs, early warning of potential heart attacks or other emergencies could be achieved, improving the response of emergency services or even allowing doctors to give treatment to patients before it happens. The aims of SPHERE are to solve real healthcare problems using technology which is acceptable in people's homes, to generate knowledge that will change clinical practice.

Virtual reality systems are just around the corner with major companies investing in the area. For example, Facebook acquired Oculus VR for a significant sum (The-Gaurdian, 2014). It is possible to imagine a scenario of a virtual reality meeting, eliminating the need for business people to fly long distances to meet face to face. In order to achieve the desired life like experience, a system would require extremely high data transfer, ultra-low latency and reliability. Current wireless networks do not have these capabilities but proposed 5G systems may do.

The described examples depict existing ideas that will come closer to being achieved with the realization of 5G capabilities. 5G will further provide a platform for new currently unforeseen innovations to flourish. These areas, and several others, provide new business opportunities encompassed within the telecoms industry. There are opportunities for these new businesses to provide their own connectivity services or form relationships with existing telecoms industry operators or businesses to benefit mutually. The significant capital at the disposal of some of these companies enables them, if the wish, to threaten existing operators by investing in their own telecommunications infrastructure and system.

## III. Problem Structuring Approach to Strategy Development For 5G

### *A. A Complex Problem Context*

We consider the development of a strategy to address research priorities in the development of 5G as a wicked problem. The following sub sections explain how a systemic Problem Structuring Method (PSM) has been used to manage the complexity of this problem and provide a structured approach to developing strategy that is likely to lead to business success in a 5G environment. However, we first articulate the characteristics of a wicked problem and why PSMs are a valid approach to take. We base our definition on the original work of Rittel and Webber (1973):

1. There is no definitive articulation of the problem situation.
2. Interventions have an impact on the problem situation, thus changing the context and leading to need for further interventions.
3. Interventions in wicked problem situations can only from viewpoints that will regard them as improvements or a worsening of the problem situation, but not solutions.
4. The complexity of the wicked problem situation means that it is impossible to carry out experiments, interventions are one-off activities.
5. Many possibilities for intervention exist, including doing nothing; articulating all possibilities may be impossible.
6. Problematic situations are likely to be part of wider wicked problems, and contain other problems.
7. Data about the wicked problem, and evidence of change after an intervention may be contested.
8. Wicked problems require action to be taken to alleviate, they are not studied purely for the purpose of knowledge gathering.

Whilst highly cited and influential across many disciplines, more recent work from Mingers (2011) summarizes these as a more succinct set and more suited for use in Systems Engineering. We have embellished his definitions with characteristics of our problem context to illustrate our point:

1. Stakeholders to the problematic situation have different worldviews.

Decision-making about technology investments in a rapidly developing field such as 5G is certain to be contested. Strategy development for an organisation requires achieving both shared understanding and shared commitment to action through a process of deliberation that is likely to start with disparate and possibly conflicting views.

2. There is no clear definition of the problem from the stakeholders.

   Section II illustrates something of the complexity of the 5G development landscape. The multi-agency nature of a 5G service as a conceptual layer across multiple elements from multiple suppliers indicates a step-change in both technology and business models making the problem situation highly ambiguous.

3. The objectives of any intervention require agreement that is difficult to obtain.

   The existence of multiple routes to market for exploiting 5G technology development poses a huge challenge to conglomerates to agree where best to direct effort to extract value from intellectual property (IP) development.

4. Definition of success for interventions requires agreement between stakeholders.

   Perhaps the most difficult aspect of strategic development is deciding among the stakeholders measures of success. From the Rittel and Webber definition above there is unlikely to be a clear finishing line for declaring a successful exploitation of any technology development in this space. Conventional measures of return on investment (ROI) on research investment are likely to be impossible to determine.

5. The problematic situation is characterised by high levels of uncertainty.

   While forecast and foresight methods will provide predictions concerning technology developments, the truth is that disruptive events may lurk in the future to disrupt the best-laid plans of any strategic decision-making process. Being aware of the fallibilities of projecting the past into the future must be part of any strategic decision-making.

Problem Structuring Methods have been proposed as a valid response to dealing with such problems and there is wide literature on defining their characteristics e.g. (Yearworth and White, 2014; Ackermann, 2012) and an even broader evidence base of their successful use in many domains. Recent work has also shown how problem structuring can be seen as an essential activity in an enlarged scope for Systems Engineering practice (Yearworth et al., 2015). Here we follow the Generic Constitutive Definition (GCD) of PSMs from Yearworth and White (2014) as an articulation of the key properties of a PSM and use them in the design of our approach. This is described further in §D below, but first we must also cover the problem of modelling 5G technologies and the integration of such models into the problem structuring approach and also address the question of who the stakeholders are.

### *B. Modelling 5G Technology Development*

Mingers (2003) summarizes different techniques and modelling methods common with systems thinking and we suggest where and how they could be applied in relation to 5G. The paper provides a framework for categorizing different techniques and indicates the philosophical viewpoint of each of technique explaining the ontology, epistemology, and axiology, i.e., *what* they model, *how* they are modelled and *why* they are modelled. This in turn indicates the stakeholders to whom this technique may be of interest. The paper implies whether the technique is used to model physical (i.e. tangible items), social (i.e. the effects it will have on businesses and the economy) or personal (i.e. how a particular user will interact with it) aspects of 5G. Consideration of the philosophical paradigm is important in modelling 5G, more so than with previous generations of mobile technology. Earlier generations of mobile technology were driven by performance-oriented goals of speed, latency, and coverage. This required a positivist approach, i.e., designing a system and showing, via testing and mathematical modelling, that goals had been achieved. The goals of 5G are much more stakeholder experience-driven (i.e., does it fulfill their needs to a satisfactory extent) and so require a more phenomenological approach, taking into consideration the needs of all stakeholders and understanding that these are unique. Different stakeholders, e.g., mobile users, autonomous vehicles, e-health, and operators will have a different measure to be satisfied by their experience of 5G such as speed, reliability, revenue it can generate, and others. By using a multimethodological approach (Rouwette, 2011; Mingers, 2011; Rosenhead, 2006; Mingers and Rosenhead, 2004; Rosenhead, 1996) combining the discussed techniques , all areas of the 5G system can be covered. There are further techniques available not covered in Mingers (2003) and it may be possible to use some of the techniques for purposes other than that described which may change the underpinning philosophical assumptions. However, at a fundamental level the mixing of such 'hard' systems modelling into a problem structuring approach is well understood and entirely feasible (Kotiadis and Mingers, 2006).

The models were developed by group model building by a group of academic researchers with expertise in a variety of technologies from all aspects of the telecoms industry including the PHY and MAC layers and business aspects. The models aim to use the expertise of the group in *developing a shared understanding of the 5G development landscape* from which we can draw inferences for the purpose of strategic planning for a business desiring to operate in the telecoms space as we evolve to a 5G era. The benefits of the modelling approach and what we can learn from it are discussed below.

### *C. Understanding the Stakeholders of 5G*

Figure 3 demonstrates stakeholders' interest and their influence on the development of 5G. Further these are grouped by different colored boxes roughly categorizing them as regulator, business, demand and technology drivers. All are contained within a larger box indicating the economy and environment.

Figure 3 – 5G Stakeholder Influence Vs Interest Diagram

The purpose of this stakeholder modelling is to make progress to understanding how their behaviors can be represented and analyzed to help visualize abstract threats, opportunities or other previously not considered issues in relation to the telecoms industry and how it will change with the launch of 5G (Walker, Bourne and Shelley, 2008). The capability to comprehend the often concealed power and influence of various stakeholders is a vital skill for success in a complex project. Stakeholders can be a significant asset - contributing information, intuitions and backing in defining a project and realizing its execution. Any tools that help to identify and visualize stakeholders' likely impact advances our ability to address the complex problems and views of different stakeholders and their relationships (Walker and Bourne, 2005).

All the regulating bodies fall in the top right corner of the diagram indicating they have high interest and high influence in the development of 5G. Technology companies span the range of the interest scale but overall sit lower on the influence scale than regulators. No matter how innovative or brilliant a technology developed by an organization, if the regulators chose not to include it in the 5G standards, it will not have any impact. All the developments of technology companies are at the discretion of the regulating bodies. The regulating bodies are further embedded within the broader business category.

The market demand box falls in the top left corner of the diagram indicating low interest but high influence. There is not presently great demand from mobile users asking for 5G; however the continual increase in demand for data due to the increase number of connected devices and popularity of multimedia applications along with increased demand for improved coverage and reliability is a significant driver for development of a new system.

Business encompasses a large area of the diagram, some businesses interested in 5G have very little influence on its development, other larger organizations hold significantly greater influence. A significant driver for 5G is enabling new profitable businesses. Operators have seen a decline in revenue over recent years and see 5G as a new way of making money. Major players from other industries are looking to invest in telecoms as an opportunity to expand their source of income. New businesses developing novel ideas on the platform of 5G need to make profit to survive.

Mapping the stakeholder influence identifies the highest priority groups and which has the most power. In trying to determine what 5G will look like it is perhaps most sensible to understand the vision of operators, regulators, and government – who are identified in Figure 3 as those with the highest influence. Mobile users are a high influence but low interest stakeholder. It is important during the development of 5G to engage with high influence stakeholders. As we approach 2020 and the expected first release of 5G we should expect to see users move position in Figure 3 further to the right. Those whose interest is already high such as operators must engage with users to ensure a satisfactory solution is reached. Consideration must be taken of those who fall in the bottom right of the diagram. Several key European projects that are developing in 5G technology and strategy, have spent significant effort on identifying requirements through user driven use case scenarios. Technology developers and academic researchers should be of particular interest to higher influence stakeholders since there is a chance their influence could significantly increase with new technology developments. The development of a disruptive technology could boost one of these to the top of the diagram. Those that fall in the bottom left of Figure 3 should not just be disregarded. 5G will only be successful if all stakeholders are satisfied. The best strategy for managing low interest, low influence stakeholders would be to provide them with information; this may increase their interest in moving to the right in the diagram, perhaps encouraging them to engage more with the development of 5G, bringing to light more information from which those with higher interest and influence can learn. Any business, existing or new, will need to engage with and understand the perspective of all stakeholders to best position themselves to be successful. An understanding of the role of other businesses / stakeholders and how changes to their operations has an effect on the encompassing system is essential to avoid systemic failure, a subject discussed in Boardman and Sauser (2013) where they demonstrate how a complex system can collapse if one part fails. The authors go on to explain that to avoid this, each part must have an understanding and level of expertise concerning the role of each of the other parts such that should they fail the gap in the system can be filled and the system can continue to operate.

### *D. Problem Structuring Approach to 5G*

Hierarchical Process Modelling (HPM) was developed as a functional technique for modelling systems using a tri-valued representation of process performance based on interval numbers (Hall, Blockley and Davis, 1998; Davis and Hall, 2003; Marashi and Davis, 2006; Davis, MacDonald and Marashi, 2007; Marashi, Davis and Hall, 2008; Davis, MacDonald and White, 2010). The technique enabled very complex systems to be modeled using hierarchical process decomposition and the interval numbers allowed for explicit representation of process performance including epistemic uncertainty, i.e., known unknowns. The value of the method has been demonstrated through application on a number of complex socio-technical systems problems in domains such as an oil exploration project, flood defense systems, asset management and performance management, (Davis and Hall, 2003; Hall, Blockley and Davis, 1998; Davis, MacDonald and Marashi, 2007; Marashi and Davis, 2007).

Here, HPM was used to manage the complexity of problem structuring in order to understand how the transformational process <*improving our understanding of the 5G development landscape*> could be achieved. This process was considered to be at the core of strategy development and the performance of the system to achieve this understanding would be affected by decisions concerning where to place resources. The process model therefore represents the top-level transformational goal as a composed set of sub-processes, structured into several layers to aid model development. Sub-processes are explicated through repeated application of a simple language game of asking *how* a process can be achieved and this continues until the successful performance of a process can be related to one or more of the technologies proposed for 5G. The model should be read as representing all the *known* processes necessary to achieve the transformational goal; in effect the model can be viewed as a conceptual system that needs to exist to achieve the transformation. Higher-level processes can be viewed as consisting of lower-level processes in a part-of relationship. Although presented diagrammatically as a hierarchy, the 'sub' processes should be understood as being *contained* within their higher-level process, not below. Each lower level is simply the higher level expanded (Figure 4 demonstrates how the process works for the given transformational process). The technique is similar to the Purposeful Activity System modelling (PAS) that forms the core of Soft Systems Methodology (SSM) (Checkland, 2000; Mingers, 2011).

Figure 4 - Hierarchical Process Model (HPM) under development representing part of the final model presented in Figure 5. Higher-level processes can be viewed as consisting of lower-level processes in a part-of relationship.

Key drivers discussed are related via stakeholder drivers to the core technologies of 5G. The final diagram resulting from the group model building session can be used aiding understanding of what 5G will encompass and further analytically to identify key technologies or aspects on which particular characteristics of 5G depend. The model evolved over several iterations and continued discussions with the group. The final model broke the highest level statement into three statements which represented the three main forces driving 5G; users, operators, and regulators. These were further broken down into lower level processes until the high level requirements could be linked to specific technologies. Additional annotations and sub categories are added the model after the development process to help communicate its findings (see Figure 5).

The 'Technology requirements for 5G' section of Figure 5 could be considered technology challenges and similarly the adjacent box organizational challenges. The technologies appearing most frequently in the 'Technologies for 5G' box could be thought of as the most essential. Where a technology only connects to one challenge, that technology may be critical to that challenge. It is likely that as time progresses, new technologies will be added and some may move position on the diagram. The diagram could be further expanded by further dividing the lowest level section, 'Technologies for 5G', into their components. The diagram builds a conceptual vision of how all the proposed technologies of 5G are linked. The 5G system will be a complex socio-economic-technical system which will integrate different communications sub-systems that use one or a few specific technology solutions and network architectures into a single larger system. The technologies and techniques described include, but are not limited to, cellular based systems and further include systems to support the cellular network such as WLAN and capillary networks.

The application of HPM indicates the importance of different technologies to 5G. It shows some particular aspects of the overall network to be dependent on certain technologies; however, the overall indication it gives is of the need for all these technologies to work harmoniously to achieve the overall 5G network. It clarifies the diversity of user, operator, and regulator demands and illustrates that the network will have to continually change and optimize for the changing demand and requirements. This indicates the need for an 'agile network' a phrase that nicely summarizes the in-depth description of 5G requirement from the point of multiple operators by the Next Generation Mobile Networks (NGMN) in their most recent white paper (NGMN Alliance, 2015).

Figure 5 – Hierarchical Process Model (HPM) Final. Reading down the lower-level processes explain *how* the higher-level process to which they are connected can be achieved. Reading up the higher-level process explain *why* the lower-level process are necessary.

## IV. Implications of Problem Structuring

We discuss our problem structuring from the point of view of an equipment vendors' research and development lab whose interests center around developing technologies to incorporate into future products or building an intellectual property portfolio for potential licensing. We take a historical perspective for this discussion and reflect on the future landscape of 5G.

Having developed a model via HPM we are now able to begin analyzing our result. From the model (Figure 5) we can populate the first two columns of Table 1 in Appendix A. The technologies are sorted in order of their HPM process connectivity score i.e. the number of connections a technology for 5G in the lowest layer forms with the layer above. All the technologies listed are proposed 5G technologies and therefore may form a part of the 5G system. Further we now populate the third column of table 1, '5G likelihood', rating each individual technology as likely, very likely, or definitely. This uses expert opinion of the same group that constructed the HPM to form a judgement on the current state of development of the technology and its inclusion into the standard. We base our decision criteria on Technology Readiness Levels (TRLs) as defined by the Horizon 2020 Work Program 2016– 2017, however we simplify the nine categories into the three stated. For example; if a technology already exists and has been applied in previous generations of technology, and is continuing to evolve, or is newly proposed with conclusive results demonstrating its capabilities, it will be marked 'Definite'. As a further example; if a technology newly proposed for 5G is in development with indications that it will provide significant advantages for the 5G system but has yet to be demonstrated entirely conclusively or has come up against some opposition in terms of inclusion into standards, it may be marked "likely" or "very likely", depending on the expert opinion of those compiling the table and their judgement as to whether the technology will be ready for inclusion in 5G. It forms a relative scale between the technologies. This process further helps to address any conflicting requirements from the HPM by considering the influence of the stakeholders in seeing their requirement realized.

This paper has used a PSM to facilitate exploring the question of how to develop strategy for research investment in the complex development of 5G technologies. In our earlier review of the historical development of the telecoms industry we identified situations where lack of strategy led to the decline of companies. Through mapping stakeholders and categorizing them (Figure 3) we recognized the significance of a business push underpinning to stakeholders. By application of HPM we relate the business drivers of key stakeholders to technologies. To continue building our understanding of the 5G landscape we must understand how businesses manage the technologies to provide business gain in order to identify which technologies will prove popular among the stakeholders of 5G. We therefore perform a second iteration of our problem structuring methodology to explore our original question encompassing the areas highlighted as requiring further research, as outlined in section five. We develop an understanding of the 5G landscape by exploring the existing and proposed business models in the telecoms industry.

## V. Developing Understanding of the 5G Business Landscape

Systems engineering principles ensure stakeholders engagement is a priority throughout the development process of any new design, technology, or system. A systems engineering approach to conducting business in 5G environment assists in recognizing the social, policy, and business challenges involved, as well as the technical engineering challenges. At present, there is very little in the literature regarding business models for 5G other than speculation. Any stakeholder wishing to be successful in developing or operating in 5G needs a business model created in parallel to technology progression within the bounds of regulatory requirements and their progression. Therefore, the overriding challenge for any stakeholder is to create a sustainable business infrastructure encompassing technologies of 5G, and accounting for potential future innovations, such that they can be profitable while providing a high quality product or service at an affordable cost to their clients (Osseiran, 2014).

*A. The Historical Context - Understanding Challenges to Traditional Business Models*

The traditional business model of a mobile network recognizes operators owning infrastructure and spectrum, and then charging subscribers for using it; this has remained largely the same through the first four generations of mobile technology. Today mobile network operators face major challenges (Nokia, 2014). They are under pressure with revenues declining worldwide. Reasons for the decline include: firstly, a saturated market forcing down prices and therefore revenues; secondly, significant expense to operators is created keeping up with growth in demand due to the explosion in data traffic; and thirdly, operators have been slow to adapt their structure for operational expenditure relative to a rapidly evolving market. Further the impact of the worldwide economic downturn of the last decade has added further pressure to operators.

Traditional business models are also put under further pressure by changes to the wider industry such as regulation amendments, changes in enterprise behavior, new technology and changes in consumer behavior such as increased use of free communication apps taking revenue away from the operators whilst still using their network capacity. This kind of change in user behavior is a social change and a driver for change in operator business models.

As discussed in Osseiran (2014) companies previously considered IT or data-communication organizations are venturing into what was previously considered the telecoms' domain, having seen a market for functions smartphones users could benefit from such as cloud based services. This puts further pressure on telecoms companies to provide a similar service at comparable cost in addition to the standard expected cellular and data service. Upgrading the network is likely to be the biggest cost to the operator.

Further business and technology collaborations or developments might see companies outside of the telecoms world challenge or partnering existing operators (Osseiran, 2014) by investing in their own cellular spectrum and data services. With the expansion of the 'Internet of things' and emerging technologies such as intelligent transport business, giants from other industries may wish to invest either to own spectrum or in infrastructure to provide services to mobile users without depending on traditional operator networks. New niche business models face great challenges in meeting the speed, reliability, and robustness goals of 5G that users will expect at an affordable cost. Current telecoms operators may counter these and adapt their own business models, contributing their experience and expertise to developing new services and solutions in application domains such as transport, energy through partnerships with large service sector players in transport and utilities.

*B. Understanding State of the Art Business Models*

While clearly major telecoms operators will continue to play a major part in management and operation of the network, potential new major customers or potential providers such as the automotive industry and those developing 'Internet of Things' type devices and how they will shape the 5G landscape should be considered.

Looking at previous mobile technology generations, there has not been much evolution in the business models since cellular technology turned digital (Bubley, 2014). For users and operators, Long Term Evolution (LTE) is simply a faster version of 3G. The fundamental differences in 5G systems architecture (Maier and Rechtin, 2009) will require considerable changes to standardization and the business model.

The functions of a 5G business model are:

1. Express value, i.e., what is the value created for a specific business by its 5G capabilities and the new advanced features it offers.
2. Identify a market segment, i.e., who are the users of the 5G related service and what is provided?
3. Define the structure of the value chain required by the operators, regulators, and users to create and distribute the service, and determine the complementary assets needed to support their respective position in this chain. Each

stakeholder must consider their suppliers and customers, and their view of the system should extend from resources to the final customer.

4. Specify the revenue generation mechanism(s), and estimate the cost structure and profit potential given the value proposition and value chain structure chosen.
5. Describe their position within the 5G system, holistically linking suppliers and customers, including identification of potential complementors and competitors.
6. Formulate the competitive strategy by which the innovations of the business will gain and hold advantage in the 5G environment over competitors and previous strategies stemming from earlier generations of mobile technology.

(Chesbrough, 2007)

Some of the proposed technologies of 5G found in (Felita and Suryanegara, 2013; Andrews et al., 2014; Ekram Hossain, Mehdi Rasti, Hina Tabassum, 2014; Osseiran et al., 2014; Gohil, Modi and Patel, 2013) already exist; the challenge in realizing 5G requirements is about developing an architecture for linking them together with the new technologies.

Many goals outlined for 5G could be achieved by simple improvement of 4G systems. For example, complete nationwide coverage could be achieved by improving the current infrastructure and high speed could be achieved by improved spectrum optimization. Technology can be viewed as a way to fulfil a purpose as explained in Arthur (2009). The author explains new technologies are not always inventions that come out of nothing, most new technologies are constructed by combining existing ones. This definition would suit the development of wireless communication, existing technologies being brought together to realize a set of goals will see the realization of a new technology. Evolution of 4G and the incorporation of new technologies and stakeholders will form 5G.

In the modern world, businesses are recognizing the power of wireless connectivity as a platform for innovation. This paper argues that 5G will impact the process of innovation, a key procedure in the creation of value. 5G will provide a platform for interactivity. Business engagement with customers, robust reliable communication, and increased speed and flexibility will generate novel ways of generating revenue (Andrews et al., 2014). Companies can use the capabilities of 5G to engage customers in collaborative innovation.

Nokia Siemens Networks identifies three strategies mobile operators or other businesses might pursue for a 5G era depending on their capabilities and market conditions:

1) "Smart delivery": providing user specific cleverly managed services to generate additional revenue opportunities by collaboration with content providers and global service operators.
2) "Value added retailer": by considering each user as unique and effectively designing their service to reflect this, value can be added by improving the quality of service.
3) "Effective brokering": by monopolizing on the capabilities, knowledge and assets existing operators have available such as customer loyalty and market awareness. It may be possible to occupy a brokerage role bridging a gap between mobile users and businesses that may mutually benefit each other.

(Nokia, 2014)

Some aspects of 5G will likely be incorporated by a simple adaption of operator's existing business models (Osseiran, 2014). However 5G will see significant technical advancement from previous generations. This state of the art type technology needs to be matched by state of the art business techniques. The strategies posed by Nokia Siemens illustrate the sophisticated business acumen required to support the sophisticated technology. The proposed strategies further extend beyond operators to others looking to profit in a future 5G environment. "Smart delivery" is something app developers must consider when designing their service to make it user specific. Many IoT companies very much fit the description of "value added retailer"; by collecting data they become unique to their user and provide feedback or benefits. As new big players, such as those from the automotive industry, look to gain from 5G effective brokering, in terms of both assets and customers, could prove beneficial. The second largest US mobile network operator by number of users, AT&T previously announced at their 2014 annual developer conference in Las Vegas, that they consider connected cars as one of the next big growth opportunities (Taylor, 2014). The automotive industry and telecoms operators will both be looking to develop business models and investment strategies that best position each of them and their respective customers as this market develops.

The three proposed strategies are closely interlinked and are strengthened by each other. For example, a value added retailer strategy may be applied to develop the best quality of service for the customer and then smart delivery techniques may be applied to deliver that service in the most cost effective way to the operator there by maximizing the operator profit. They may work together perhaps all applied by one large company in different divisions or applied by more specialized companies collaborating.

Methods of charging and billing customers will likely diverge from existing methods. With the increasing number of free communication apps and free wifi access points, along with technologies such as D2D emerging and providing communication without going via the spectrum, operators will need to provide good incentives, i.e. very high quality of service, for users to pay for their services. Other businesses may look for alternative revenue streams from users with connectivity as a free service to attract customers.

A principal analyst with Quocirca, the business and research house, is referenced in Gold (2014) speculating usage costs moving on from call time and data speed calculations to layered speed-based charging. They state that a universal basic relatively low throughput service may be offered, at no charge or minimal cost for all devices, with the option for additional tariffs as the data speed goes up. 5G services are likely to be available to everyone on a speed-based pricing model allows users to choose which speeds they wish to pay for.

Yazici (2014) further discusses the idea of a layered model proposing the Network Controller on top of the pyramid. Various operators could apply this business model as part of a software defined architecture would govern QoS provisioning from operator to user, application-aware routing, user mobility, political issues and revenue generation, delegating to several lower level control processes. The architecture proposed by the authors introduces an integrated service methodology to mobility, handoff, routing management and connectivity management. Organized by complex control plane functions, this architecture also suggests a speed or data flow based charging system.

### *C. Applying Problem Structuring - Systems Analysis of Business Models To Further Aid Understanding*

Table 2 summaries potential business models that may emerge during the evolution of 5G. The information summarizes content presented earlier in this paper and is further influenced by (Nokia, 2014; NGMN Alliance, 2015; China-Mobile, 2015; KPMG, 2011).

Methodologies discussed in Boardman and Sauser (2013) can be used to map the potential new business models and their routes from drivers for change to the telecoms industry. Figure 6 shows diagrammatically how demands on next generation networks drive either continued development of the traditional operator owned infra structure service model or new business models (smart deliver, effective brokering, value added retailer).

Figure 6 – A systemigram illustrating the link between 5G drivers and the development of business models

The process of reviewing the telecoms business literature and mapping the drivers for development of the business models further aids us in developing an understanding of the landscape of 5G and achieving more informed decision making in relation to strategy for research investment. The process provided an understanding of how technology areas which one may wish to invest research effort into might be utilized. Despite the potential benefits, a technology that cannot be incorporated into a business model is unlikely to be widely used and therefore may not be a sensible investment of research resources. This understanding provides us with confidence in relation to profiting from or risk losing from our investment.

From our improved understanding of the 5G business landscape we can now further develop the table in Appendix 1. Our improved understanding enables us to complete the fourth column of the table 'Action'. Each technology is assigned a letter A, B, C, D, or E according to the key at the bottom of the table. Further the comments column of the table is also populated where further explanation or justification for the decision is needed.

## VI. Reflections On 5G Strategy Development

Establishing a process such as that recommended in this article minimizes the risk of strategic failure due to lack of understanding of the surrounding system (Boardman and Sauser, 2013). Through continued iterations, the process will remain largely the same, however, as the surrounding system develops the models will change to reflect that. In this situation knowledge and understanding of the benefits of an established process is as important as the content knowledge.

The iterative process presented in Figure 7 includes the loop reviewing the history and state of the art. It may seem at first that these will only need to be done at the beginning of the process; however, this is not ideal for the following reasons. The initial historical review, as presented earlier in this paper, is to provide context and understanding. In an industry of the scale of the telecoms industry, review the entire history in detail is not feasible. Instead, the best approach is to use some expert judgement and investigate areas thought to be significant. Moving further through the process presented in Figure 7 will highlight other areas as important. Further exploration of the history in relation to these newly identified important areas may be required in additional iterations of the loop. Similarly, with reviewing the state of the art, the problem structuring may further highlight areas that were not included in the first review. Further, the timescale of the loop is not specified. Continued iterations may take place over sufficient time such that the industry state of the art has moved on. In addition to this iterative process to make an initial strategic decision the whole process will need to be repeated periodically to confirm the strategy selected is still suitable and recognize any amendments that need to be made. There is no set time interval at which this should be done; a decision will have to be made taking into account the rate of progression in the industry, and in response to any changes in the industry landscape. The landscape developed from the first iteration will help users of this methodology make the decision concerning how often it should be revised.

In relation to 5G strategy, the process highlighted areas where there is opportunity for a research lab to make technical contributions with a supporting business case. The process provided an understanding of the technology and business push for 5G and an understanding of how these two drivers interrelate. The resulting understanding from the application of this process enables more informed decision-making, thus reducing investment risk.

Figure 7 – The methodology of this article, from problem statement to decision making. Key Terms: 5G – Fifth Generation Communication Systems, PSM – Problem Structuring Methods, HPM – Hierarchical Process Modelling

## VII. Conclusions

This article contributes to knowledge in the following ways: (1) by presenting a methodology for developing strategy for research investment in the complex development space of 5G technologies, (2) demonstrating how specific technical drivers of 5G are causing the evolution of the business infrastructure (3) demonstrating how problem structuring techniques can be used to develop a vision of the landscape of the 5G system for more informed decision making.

The article explored the application of systemic problem structuring methods to the development of research strategy in response to the challenges of 5G. It is hoped that the reader of this article will have developed an understanding concerning how the telecoms industry has evolved historically to reach its present state and how the business side of the telecoms industry is evolving towards 5G; the drivers for it; its complexity; and the state-of-the-art technologies that are involved.

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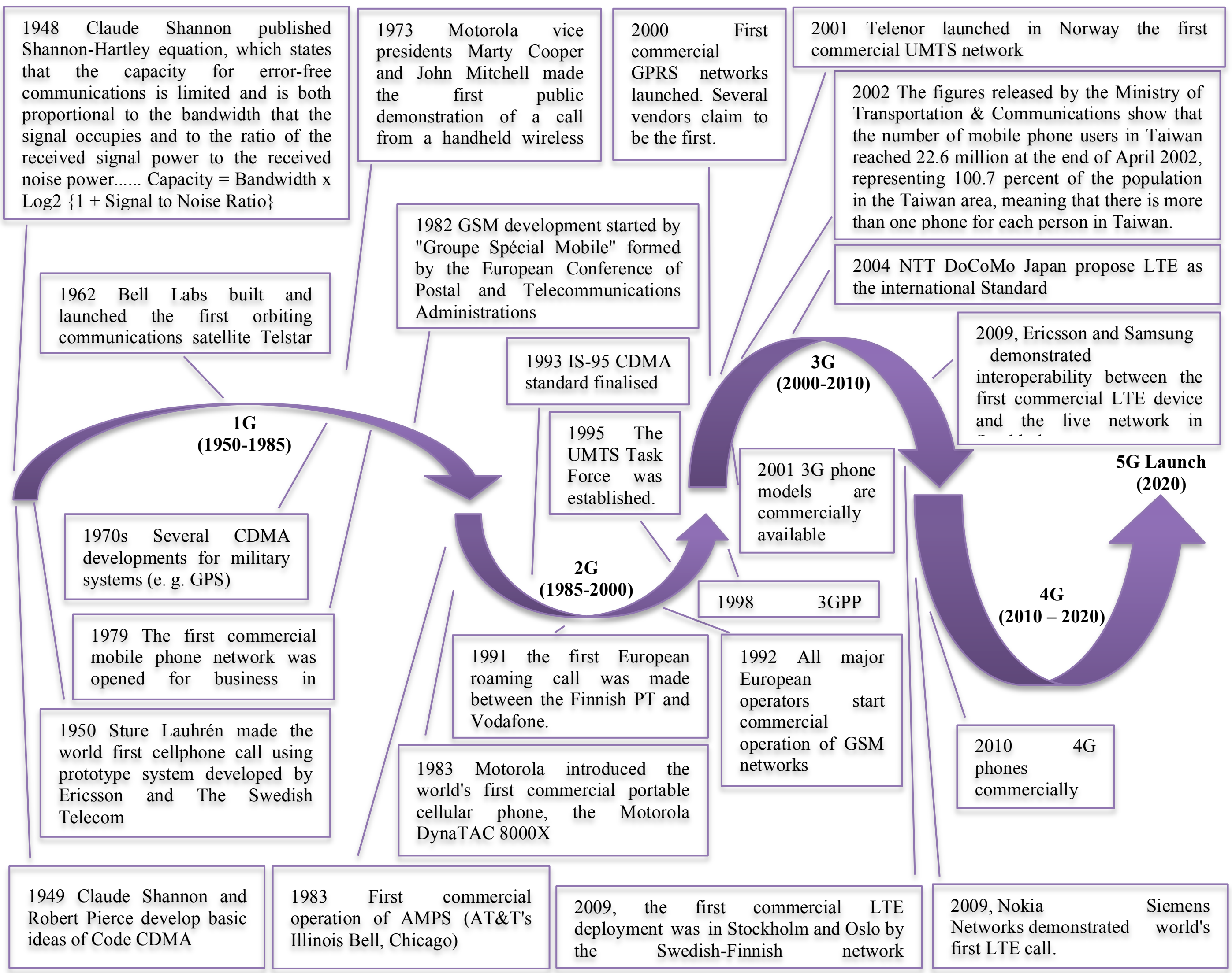


Figure 1 – Historical timeline of the mobile telecoms industry highlighting some key moments in its development. Key terms: CDMA -Code Division Multiple Access, AMPS - Advanced Mobile Phone System, GPRS – General Packet Reconstruction System, UMTS – Universal Mobile Telecommunications System, 3GPP – 3rd Generation Project Partnership, GSM - Global System for Mobile Communications, LTE – Long Term Evolution. The information for the timeline was adapted from (UMTSWORLD, 2006) and (Wirelesshistoryfoundation, 2015).

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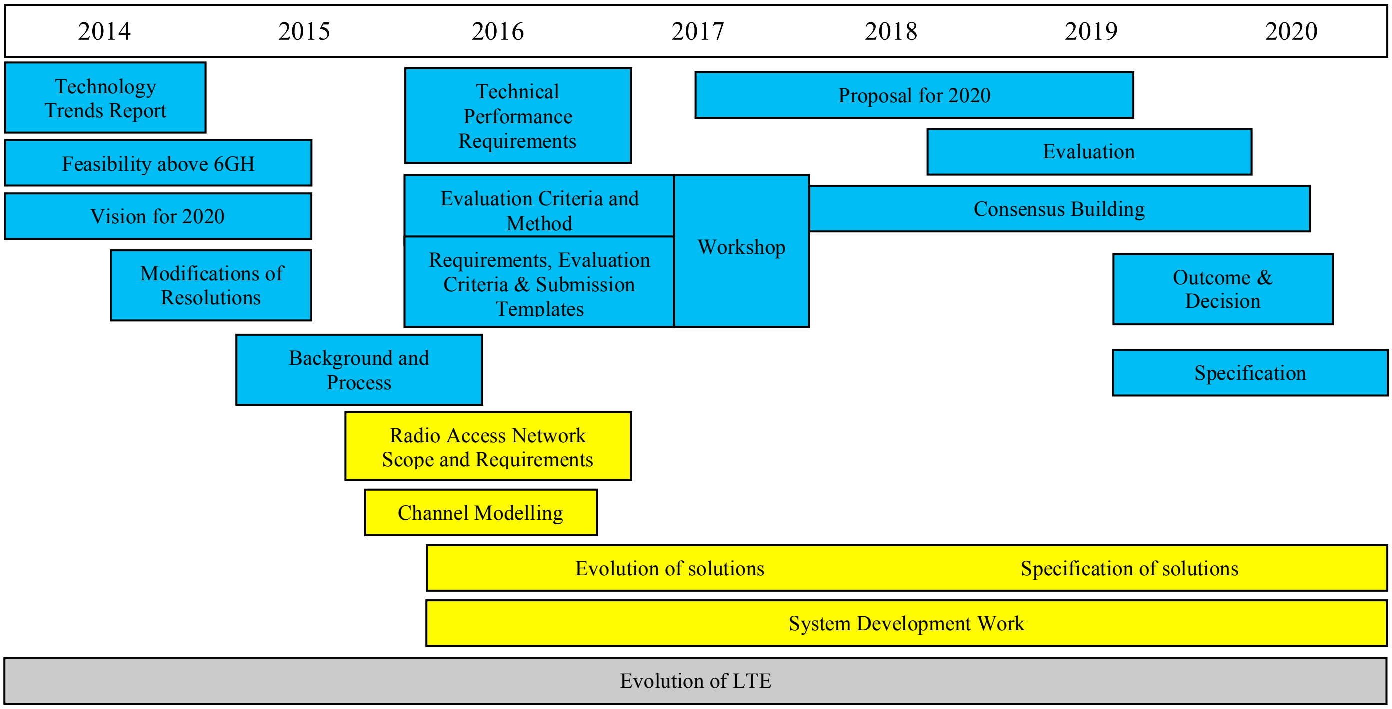



Figure 2 – Timeline to 5G. As proposed by International Telecoms Union (ITU) in blue and 3rd Generation Project Partnership (3GPP) in yellow.

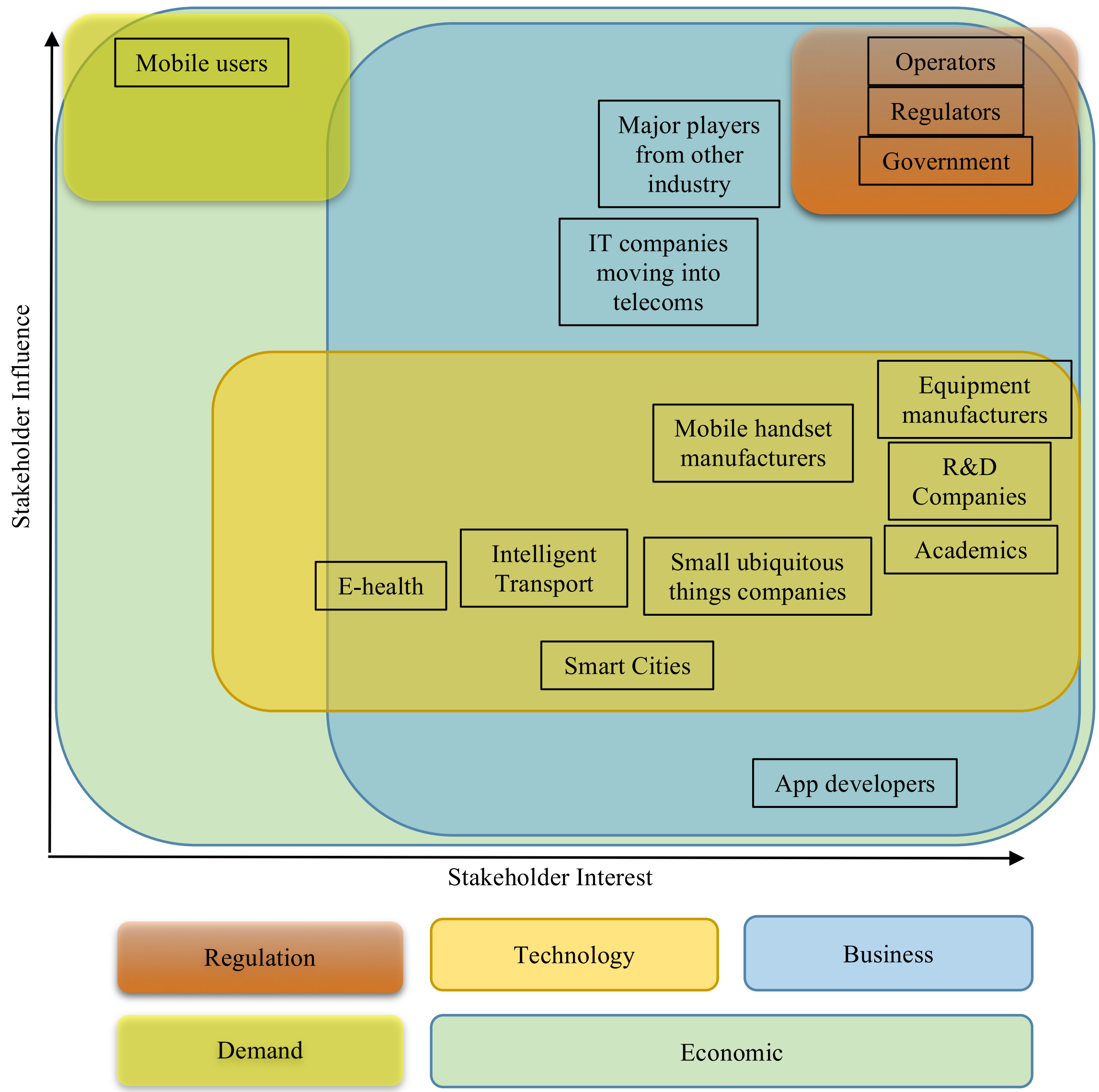



Figure 3 – 5G Stakeholder Influence Vs Interest Diagram

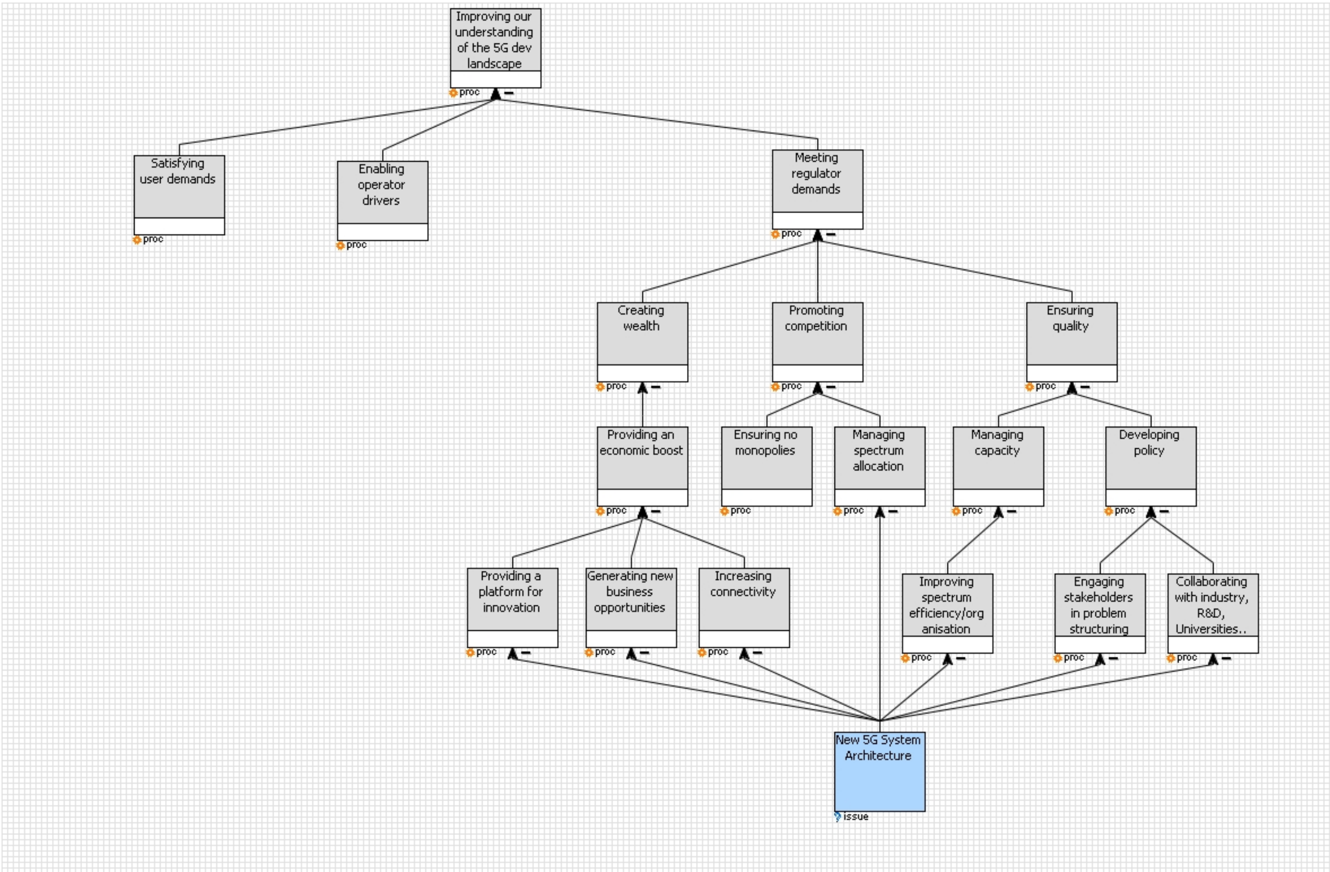



Figure 4 - Hierarchical Process Model (HPM) under development representing part of the final model presented in Figure 5. Higher-level processes can be viewed as consisting of lower-level processes in a part-of relationship.

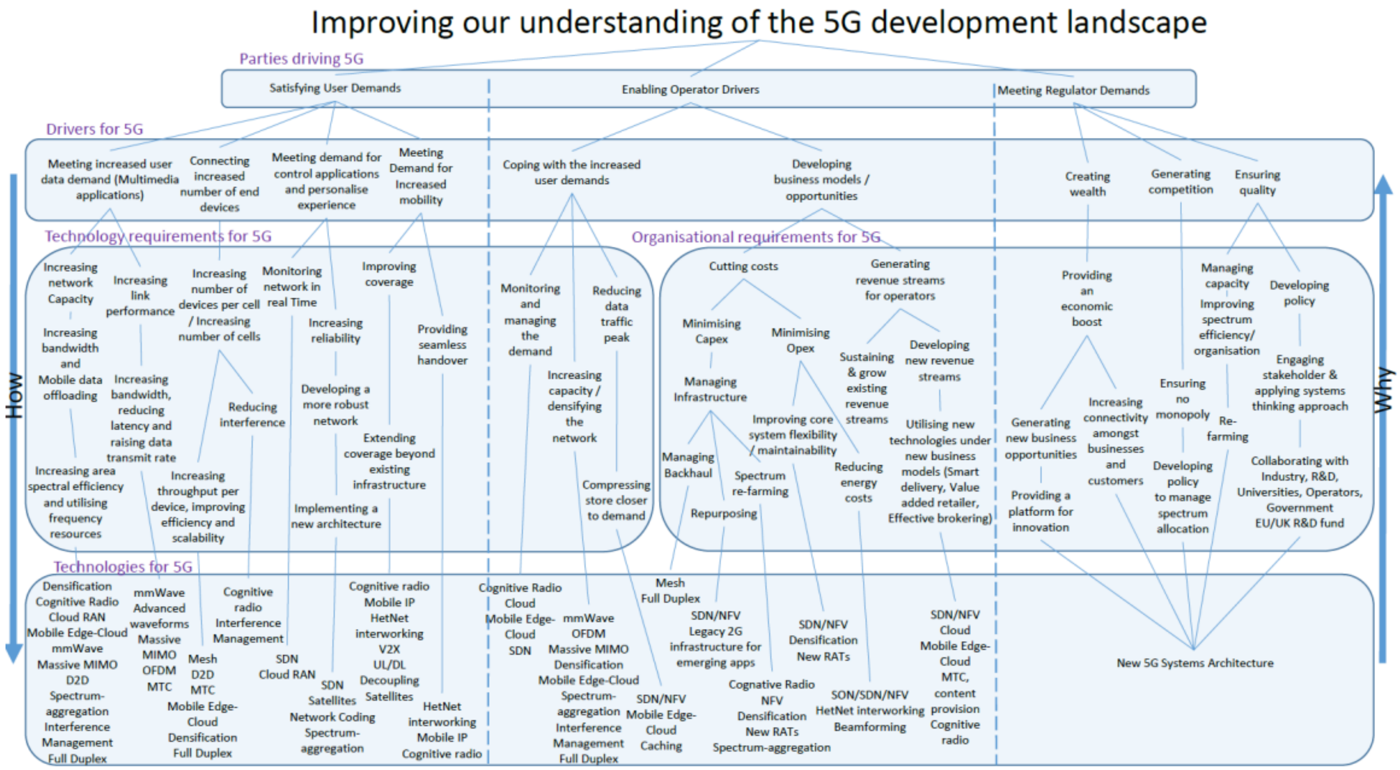
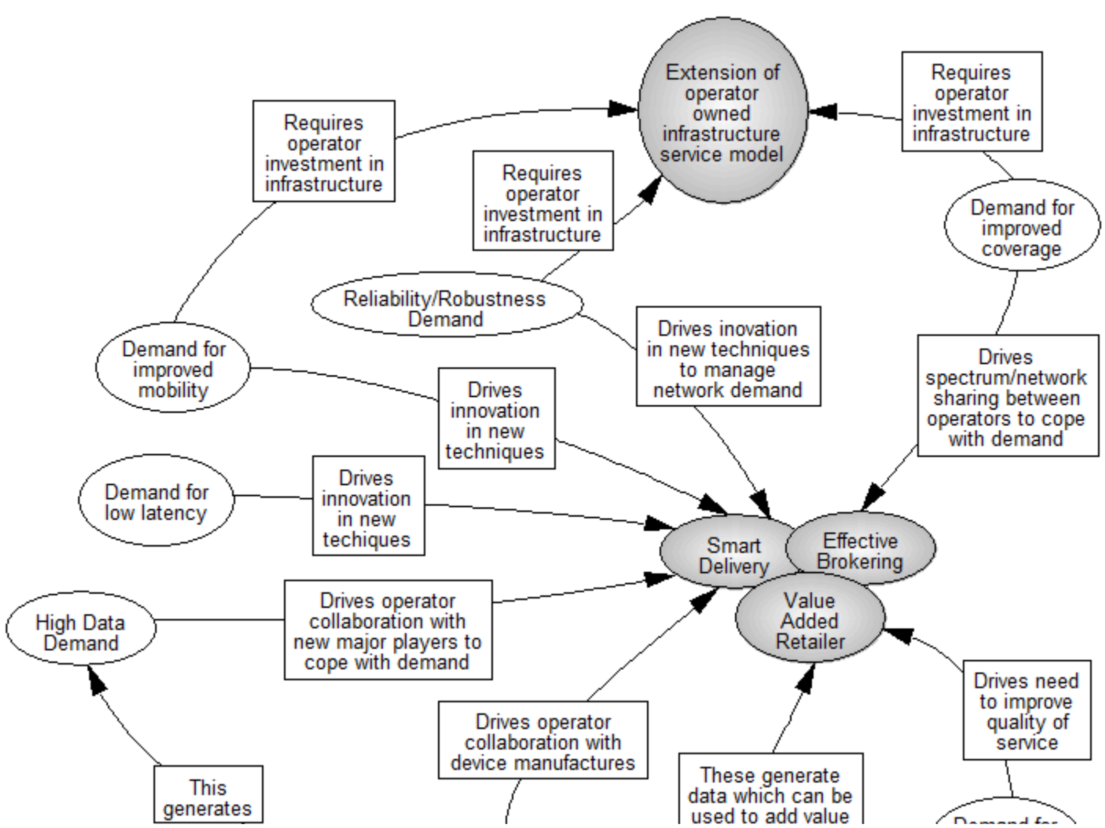



Figure 5 – Hierarchical Process Model (HPM) Final. Reading down the lower-level processes explain *how* the higher-level process to which they are connected can be achieved. Reading up the higher-level process explain *why* the lower-level process are necessary.

Figure 6 – A systemigram illustrating the link between 5G drivers and the development of business models



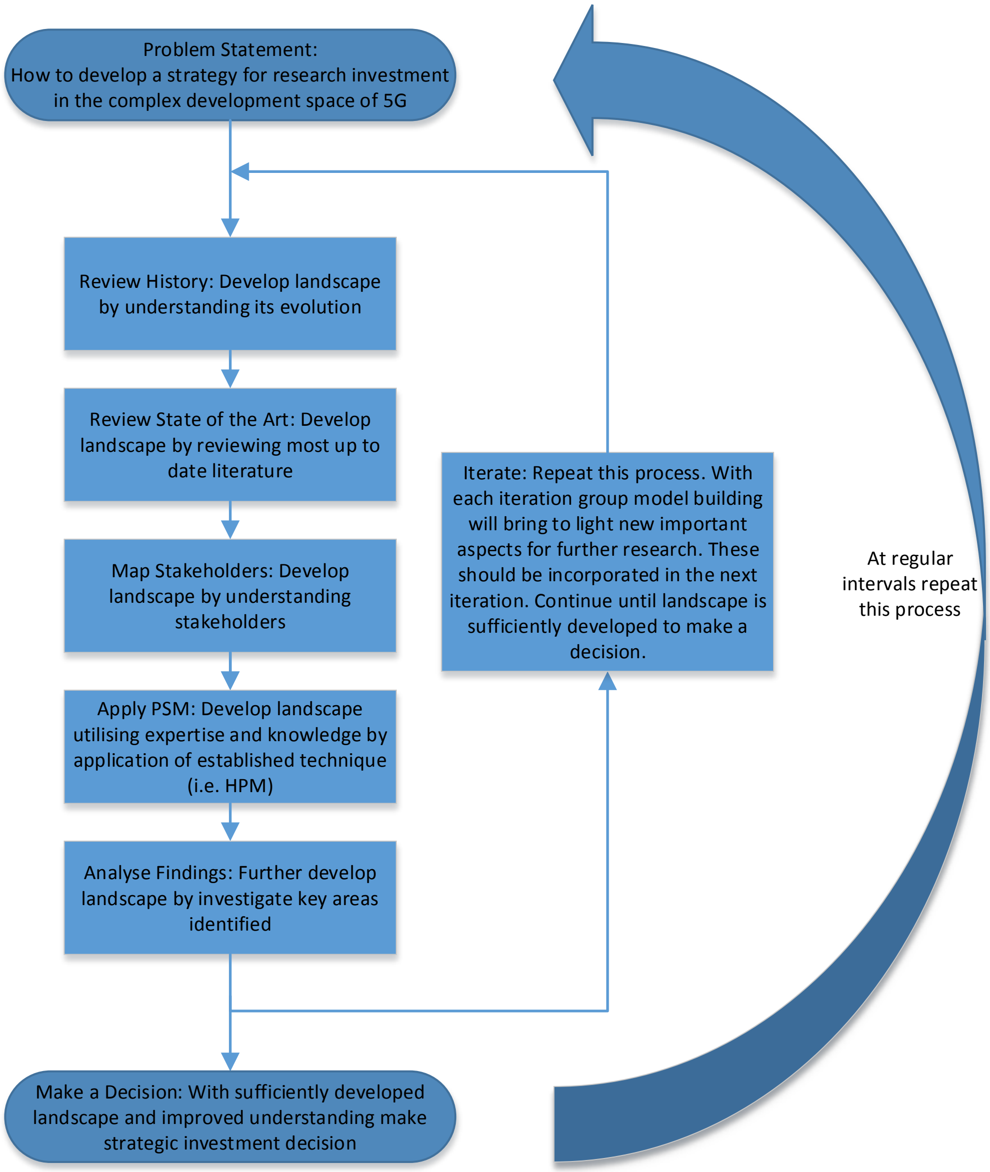



Figure 7 – The methodology of this article, from problem statement to decision making. Key Terms: 5G – Fifth Generation Communication Systems, PSM – Problem Structuring Methods, HPM – Hierarchical Process Modelling