The Future of the Internet: Scenarios and Challenges in the Evolution Path as Seen by EIFFEL Think-Tank

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***Abstract*-The paper deals with the current findings of the Think Tank group of experts from all over the world working within EU FP7 project "Evolving Future Internet for European Leadership – EIFFEL". The Think-Tank is working on meetings where the discussion about major challenges and scenarios of the current Internet is contributing to the debate about the future of the Internet trying to provide some answers and identify evolutionary mechanisms for its development. In the on-going work it becomes evident that different views exist regarding the missing parts or concepts of the current Internet network architecture. Some scenarios of Internet evolvements based on the stakeholder's incentives show divers directions of development. This paper introduces the major findings regarding the identified challenges and the evolutionary mechanism suggested by the EIFFEL Think Tank.**

Keywords - Future Internet evolving mechanisms; Scenarios and visions; EIFFEL project think-tank.

I. INTRODUCTION

The current Internet is considered as remarkable success of the technology advancement. The Internet platform enabled innovation that far exceeds the original vision of the system as a research instrument. The Internet and associated services today have transformed the lives of billions of people in areas as diverse as democracy, education, healthcare, entertainment, commerce, finance and civil infrastructure. It can be easily claimed that the Internet is the 21st century's fundamental societal infrastructure, comparable to the railways of the 1800s and roadways of the 1900s. The Internet and the associated services have contributed to the transformation of the world economy and society. They catalyse new forms of communication, collaboration, creativity and innovation. They deeply affect the human communication, interactions and transactions, and the way humans deal with information and knowledge.

All the data and statistics related to the Internet are *still* growing at exponential rates. According to the last report of the Task Force of the European Commission DG INFSO the Internet connectivity is expanding rapidly in both terms: geographical distribution and size [1]. Currently there are about 1.6 billion Internet users worldwide (from 360 million in 2000) and 4 billion mobile users (from 2.7 billion in 2006); 570 million Internet-enabled handheld devices are in use. The number of people who use the mobile phones for web surfing has doubled since 2006 [2]. It is expected in 2012 the number of mobile and wireless users to outnumber the wired ones. In parallel with user growth the stored information is growing as well or even faster. In 1998, Google indexed 26 million web-pages; in 2009 it indexes 1 trillion. There are 400 million web pages and 55 trillion links between these web pages. The Web is processing 100 billion clicks per day, 2 million e-mails and 1 million instant messages per second. Video traffic over the Internet is growing by 60% every year and will be multiplied by 1000 over the next 5 to 8 years. Web 2.0 and social networks with popular social sites are attracting more than 125 million regular users within just 5 years of existence [2]. Internet is today indispensable part of the businesses as most of the businesses processes have been significantly automated by the underlying Internet technologies in business systems, production, development and communication. The current Internet is the most important infrastructure of the digital society that is adapting itself by use of ad-hoc technical solutions that help to meet the demands of the users and devices, applications and services enabling human activities that were not foreseen in its original design.

The networking community being aware of the rising number of seemingly ad-hoc solutions to the technical problems has come to agreement that these problems are of architectural nature and for that reason a general re-design may be needed. It is common understanding of the community that the design of the Future Internet should enable smooth evolvement of the current IP network and should not lay on the current practice of patches being developed and implemented to overcome the existing tussles. It is also a common understanding that the structural and architectural problems of the current Internet cannot be solved without understanding of how a system with the size of the Internet interacts with the world either being human or just some mechanical part of it.

This paper presents some of the identified immediate problems and challenges that require fundamental rethink of the set of mechanisms in use in the today Internet and its architectural origin. It is based on the work within the EU FP7 project Evolving Future Internet for European Leadership –EIFFEL [3]. The project is organizing semi-annually think-tank meetings where technical and other experts from all parts of the world are contributing to the debate about the future of the Internet trying to provide answers to the major challenges and tussles. Most of the identified agreements and disagreements regarding the major problems of the current Internet are provided at the FIPEDIA site [4] maintained by the EIFFEL core team. This paper introduces the major findings that are presented in detail in the EIFFEL White Papers on the Future of Internet [3].

The paper is organised in five parts, the first part introduce shortly the on-going activities about the Future of the Internet around the world, then focuses on the EIFFEL evolutionary mechanism approach in developing the Future Internet and finally provides an insight to the socio-economic challenges that need to be approached. The paper ends with conclusions and ideas for continuation of the research agenda debate.

II. THE NETWORK COMMUNITY DEBATE

The networking community is aware that the Internet network in use is still based on the best-effort, point-to-point service model, well suited to applications between two endpoints that can tolerate occasional performance degradation. Considering the current level of service where performance degradation is not acceptable but in the same time many of the used applications involve multiple endpoints and their identification in the Internet network the design of the new model becomes even more difficult. Deep consideration of the alternative service and network architecture to solve the tussles is becoming even more necessary. However, the views and the approaches within the research initiatives and efforts towards Internet evolvement differ.

In U.S the NSF NetS research program FIND [6] is the major long-term initiative in the area of the Future Internet program where "clean slate process" research proposals in the broad area of network architecture, principles, and design, are trying to answer to many questions within the area of Future Internet. The philosophy of the programme is to help conceive the Future of Internet by enabling a network design that is free from the current collective mindset about the constraints of the network. The NSF is recently considering the NetSE (Network Science and Engineering Committee) report program published in mid-2009 [7], in which further of R&D activities based on theoretical approaches that help to overcome the barriers in future network design are recommended. GENI [8] is also another U.S based program focusing on a flexible and reconfigurable network “test-bed” experimental facilities and related experimental projects.

The EU through the FP7 program is engaged in funding a very wide range of research activities that relate to the future Internet. Given the scale of this activity, and the rate, at which it is generating results, a complete, up-to-date, snapshot of all related European R&D activities in the area is difficult to be provided. Some form of cross-project, cross-domain body that promote information sharing and helps to set a balance between coherence in order to exploit knowledge generated by number of participants, and the existing diversity is happening within the Future Internet Assembly that was established in March 2008 in Bled, Slovenia. FIA with semi-annual meetings is ensuring appropriate coverage of this very large and challenging research domain that includes innovative research in the area of networking, experimental facilities and testing within the FIRE [9] program. Recently the initiative related to the Future Internet enterprise system – the project cluster FInES [10] was added to the FIA program. Recently in July 2009 the final report of the EU DG INFSO [2] Task Group on Interdisciplinary Research Activities for the Future Internet was published where the design, implementation, testing and validation platforms are identified as major research challenges for the EU in the incoming years. Cross-disciplinary research activities are the essential part of these platforms. Japan, Korea (KOREN) and India have set up similar initiatives and Asia with China has as well its own research initiative on the Future of the Internet – AsiaFI. Cooperation and exchange of information between this initiative and the EU FP7 projects have been recently set up.

The Internet has influenced many changes in the world in the society, culture, commerce and technology. Activities about the Future of the Internet that includes discussions about the Internet governance and business models are on-going in other communities e.g., in the international governmental and non-governmental organizations such as OECD [11], ITU [12], UN-IGF [13]. Internet Society as well together with ICANN are developing position papers and projects on issues such as the Internet Economy, Internet Governance, Network neutrality are being presented and discussed on ITU and IGF forums. The recently expired contract between ICANN and the U.S government (NTUA) is one step forward toward building up of real internationally governed corporation and inclusion of the civil society as its constitutional part. Important observation in exploring these initiatives is that the balance between the new network design for the expected new Internet in the attempt to bias the Internet towards one particular model of governance and business model is difficult to be achieved. In other words, the architecture to be designed must attempt not to prescribe the outcome of particular tussles in the (future) market place beforehand rather than allow for tussles to commence inside the architecture at runtime. Articulating the grand challenges and working towards solutions needs a wider debate as well as concrete work among a growing community of (interdisciplinary) researchers and major stakeholders. The need is clearly understood by the members of the think-tank of the EIFFEL project [3]. Different views exist in respect of what may be missing from the current architecture or why such concepts are missing. Some of the agreements achieved during the think tank meetings are presented in the section 7 of the paper. Full report is available in the EIFFEL White paper [5] and on the recently set up FIPEDIA portal [4].

III. EVOLUTIONARY MECHANISMS

EIFFEL think-tank has come to agreement that a consideration of a large-scale system such as the Internet need to be carefully observed before starting the new design. The evolution of the Internet is becoming compromised [14] when the architecture does not allow legitimate concerns to be expressed after its original design. As a result, users, providers and business customers solve their problems in *ad hoc* ways, adding carbuncles in violation of the original architecture. Then subsequent requirements are even more difficult to satisfy, because of all the feature interactions with the number of exceptions to the original architecture.

The root of this problem lies deep in the processes used to design architectures and solutions. Currently, much emphasis is placed on the design phase of the architecture, with requirements phases and use case definitions, accompanied by processes of standardization. This *inevitably leads to an emphasis of the concerns that are important to the players who are deeply involved in this phase while often neglecting the concerns of the actors entering the scene after the solution has been fixed*. This Newtonian-Descartian concept of system design, relying on such requirements and use case definition phases, assumes the ability to capture all *relevant* concerns and therefore resolve the most probable run-time tussles at design time. The widening scope of the Internet beyond mere technology and the observed increase of ad-hoc solutions after the design of the original architecture bring this design process into question. Some authors propose [15] a shift from these reductionist Newtonian-Descartian towards Darwinian approaches [16], where the *evolutionary kernel* is a component that has been proven to be successful for multiple uses, so it may act as a platform for evolution around it, (see [15]) and becomes the design process itself, i.e., a process, in which concerns of actors are incorporated into the system at runtime, recognizing the inability to cater to all possible requirements during design time. However, this requires an understanding of what had been good and should be preserved or used in the new design.

These consideration and agreements achieved during the discussions of the Internet evolution can be summarized as follows:

- There is a need for evolution as a gradually developing process, like for any large-scale system. This evolution of the system is particularly important considering the evolution of society due to the impact of the system itself. In order to understand the suitability of the system to evolve, we need to understand the dynamics forcing the changes and devise an architecture that is suited for these dynamics to commence in runtime. These dynamics will need to define the required steps and their size in evolution that is being necessary and therefore the changes in the underlying architecture that are being required.
- The scope of the dynamics affecting change of the Internet is widening. The Internet has become more than a technical artefact – it has transformed from a network for geeks to a crucial infrastructure used in society and business. Its impact on these areas is obvious, from e-commerce to e-government, the change in the perception of privacy to many other societal changes since its introduction. The virtual and the real world abide to similar rules regarding human rights and respect for personal space as guiding principles. Hence, the question of evolving the Internet is not a mere technical one anymore.
- Evolution speed is increasing with the advances of technology. For instance, memory is becoming so cheap, in particular compared to the formative years of the Internet, that solutions for caching vast amounts of content locally is likely to transform the way users and customers deal with content.
- In that context another problem needs immediate attention: consumption of energy related to increase of used memory and processing power. Internet is become another area for energy saving and low energy consumption devices on infrastructure and on application level.

Coping with the changes and the research agenda preparation is the issue discussed and worked within the think-tank meetings. It was obvious that the old models of the development mostly based on engineering approach are no more sufficient. The complexity of the system and the interrelation with the society needs scientific methods based on facts and measurement to understand and react to the global picture and the expected evolution in search of solutions.

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IV. POSSIBLE RESEARCH METHODS

The basis of scientific research lies in the ability to formulate and test falsifiable hypotheses. The role of engineering is to create, evolve and maintain operational systems according to a particular design brief. The Internet provides an environment that is rich in possibilities for research that is experimental and analytical, which at the same time, must be set in the context of engineering; likewise, Internet engineering must respect the need to use the engineered system as an experimental platform and as a platform for innovation, both of which might cause the underlying design brief to change.

The Future Internet is, consequently, more about process than product. Although it is likely that a Future Internet will result from agreement by committees representing industry players and governments, it is crucial for individuals (including researchers) to understand how to influence the key decision makers to eventually adopt the 'right' solutions. The present Internet design is taking part within organizations that have historically focussed more on engineering than innovative vision and social interactions. Some believe the future Internet will come about through the same institutions that fostered the current Internet; the networking research community and the Internet Engineering Task Force (IETF), but this is unlikely to be realistic, simply because the importance of the Internet has changed with time and the list of stakeholders with an interest in design outcomes has grown. As things stand, it is undoubtedly the case that many proposals will be standardised in a variety of committees belonging to several associations. Those proposals that are most worthy and manage to attract support of the key stakeholders will be deployed, and those that survive the rigours of the marketplace will become the Future Internet.

In the same time it is obvious that even very successful network architectures should change over time and this fact should be present in the overall considerations of the future of the Internet. All new systems start small. Once successful, they grow larger. The growth brings the system to a new environment that the original designers may not have envisioned, together with new requirements that must be met. For example the security threats facing the Internet in recent years should not be blamed upon the inadequate design of the original architecture. Rather, it is due to poor understanding of its limitations and the missing adoption from the users. Continued success requires continued scientific research on networking practice, to identify new problems and evolve the architecture to meet the new demands.

Another aspect that needs to be addressed is full understanding of the driving forces behind the Internet's success. The Internet would not have succeeded so greatly without Moore's Law. Computing technologies are moving forward with accelerated speed. The Internet architecture facilitated the technology advances. The rapidly advancing technologies in turn drive new application developments and user population growth on the Internet.

Technology advances and Internet growth have created the new demands on the architecture. The need for security, manageability, and scalability showed up over time. Today they are more pressing than ever, as they were not promptly identified and fixed ahead of the crisis. This requires continuously identification and address of the new demands. One unfortunate fact to be claimed is that there has been a big gap between reality and how the research community understands it. Since the Internet commercialization in mid 90's, the networking research community gradually lost touch with the frontier of the Internet, lost the opportunity to observe real problems. The community by and large retreated back to work on isolated or point problems, and used simulations or small, isolated test beds for design evaluations. The research community's lack of attention does not mean real problems do not occur, but only that the problems are solved by others frequently on ad-hoc basis.

Designing a technical system creates an economic one, while the latter is enabled by a variety of technical systems. In reality however, the process of (technical) system design is mostly disjoint from the process of designing business models and strategies for sustaining them over a period of time. Combining these two processes is difficult, largely because of the communities that are required to interact. The challenges are in the sustainability of the systems, which cannot be assured without a joint design process. A solution to this problem will not only have an impact on the design of systems but also, for instance, on the way the educational system shape the talents in their understanding of these fields, as has been recognized during the debate of the EIFFEL think-tank [3]. For this to happen, however the differences of *research styles* that exist between research fields, like economics, engineering and social science should be accommodated and make usable in the engineering design.

V. INTERNET SOCIETY -ISOC SCENARIOS

The Internet Society (ISOC) [17] contributed to the EIFFEL think-tank discussions with an illustration of the possible evolvement based on the »Internet Futures Scenarios" exercise done in 2009. This exercise produced four visions of possible future in cases when stakeholders' interests could achieve dominance in the practices development. The scenarios are presented on Fig.1. The scenarios illustrate possible futures designed around two axes that point to different outcomes: whether the future Internet will remain true to the old open Internet model (generative, rather than reductive) or whether it will become distributed and decentralized. Other alternative is the Internet to become a subject to command and control of regimes. These axes represent two key areas of external world tussles (social, economic) between Internet stakeholders, impacting the deployed Internet reality.

Together, they form four quadrants, each of which can be described as an illustrative scenario.

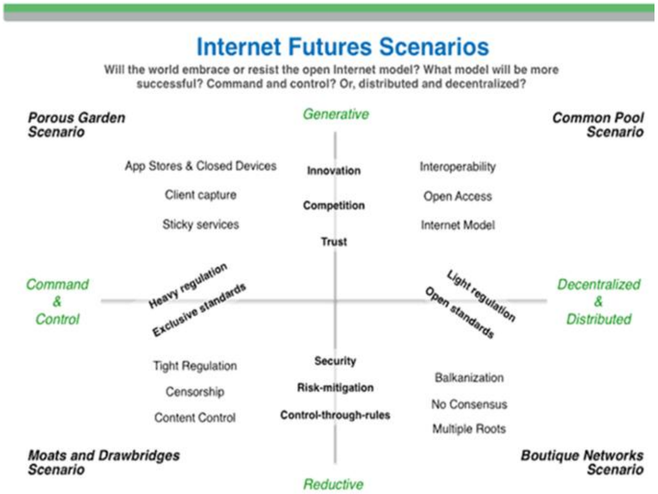

FIGURE 1: ISOC FUTURE INTERNET SCENARIOS

The quadrants between the two axes reflect the effects of misalignments in the incentives of the Future Internet between stakeholders. The main incentives and what drives the stakeholder's actions are presented on Table 1. The columns provide categorization of the major stakeholders in regards to their fears of and what they are greedy about.

TABLE 1.INTERNET STAKEHOLDERS INCENTIVES

	Fear	Greed
End Users	Privacy, Overcharge, Pricing Unfairness	Cheap/free services, Cheap/free content, Cheap/free network access
Service/Content Providers	Losing their market share because of competition, innovation and regulation	Market dominance, Monitor users' behaviours, Tiered Services (no network neutrality)
Network Providers	Losing their market share because of competition, innovation and regulation	Market dominance, Monitor users' behaviours, Tiered Services (no network neutrality)
Governments	Security, Politics	Control of Content, Control of Access to Content, Monitoring (Spying) Users

The scenarios consideration has shown that among the four quadrants the Common Pool quadrant is most positive regarding the "generative" and "distributed and decentralized" properties of the Future Internet. All resources that are part of the future Internet are made available in the "Common Pool" scenarios to the overall community. This scenario can be considered as the ideal, for which Internet development and deployment has always striven, though never achieved in perfection. This scenario tends to provide maximum flexibility and deployment, innovation and opportunities to all stakeholders. Technologies are planned to be built out "horizontally", rather than in full service verticals. This quadrant is named as a Common Pool in order to reflect the notion that it represents for the future where (information service and application) gardens will not be completely walled, but still somewhat restricted to particular channels.

The Porous Garden scenario is designed around the stakeholder's incentive for increased control over business and revenue. In this quadrant the application and service provider stakeholders are leading the evolvement with architectures that feature increased command and control in the "vertical" services. In this vision of the Future Internet, the networks remain global but access to content and services are tied to the use of specific networks and associated information appliances. Financial incentives for content producers and software developers would result in continued innovation within the appliance-based model, but network operators will be constrained to evolve their services to support appliances and not the general Internet services. Consumers would have to purchase multiple appliances and associated subscriptions to avail themselves of the full range of innovation on the network. This scenario reflects the general mis-alignment between the incentives of the content producers and those of end users, as well as (ultimately) the network operators.

The Boutique Networks quadrant present a scenario where applications are not expected to be the dominant driver of the future but contrary to that allows the networks to be. This quadrant reflects the possibility of network specialization to become dominant. In that case Internet is not expected to be a single, general network, but rather individually constrained and composed from purposed networks that provide "boutique" services. It envisions a future in which political, regional, and large enterprise interests fail to optimize on the social and economic potential of a shared, global set of richly connected networks (the today Internet), but instead reflects the outcome of parties intended to optimize control in small sectors (political and otherwise). While these balkanized networks continue to leverage the benefits of existing Internet standards, they do not collectively provide the basis for generalized application and service development and deployment. In that regard, this quadrant represents the converse of the Porous Garden quadrant, in that it is network development interests that are expected to dominated.

The Moats and Drawbridge quadrant reflects a future where stakeholders are seeking tighter command and control and more reductive, constrained network environments are expected to prevail. The increased (perceived) need to provide security and consistent environments through "command and control" operation and closed development practices, this scenario is drawing an Internet that is heavily centralized, dominated by a small number of big players who create their own rules in a few "big-boys" clubs. In this scenario it can be expected strong regulation as governments will seek to impose some public interest obligations on the industry, as the user interests and incentives will not be natively supported. Control could extend to limiting equipment that could connect to the network, content could be proprietary and protected by strong intellectual property rights. This quadrant shows the highest barrier for entry of new applications, networks, services and end users.

The description of the above scenarios allows a selection of the best vision based on the consideration discussed at EIFFEL think-tank meetings. From an economic point of view (the most democratic at least), the perfect scenario would be the one that exists in a perfect market; the one for which the following statements are true [18]: Perfect market information, No participant with market power to set prices, No barriers to entry or exit and Equal access to production technology.

An immediate result of the perfect market information should also be the existence of perfect pricing mechanisms. Doubtlessly, the Common Pool scenario is the one that mostly resembles to the perfect one and is close to the current "ideal". The significant question here is if it is possible to influence the design of the Future Internet so that it can naturally stabilize itself to this quadrant (or towards to a perfect market)? The answer is probably "yes" and the way to achieve it is via a design for change. In that context a special attention has to be paid to the information part, which in a network based system translates to network measurements and monitoring

VI. BUSINESS AND SOCIAL DEMANDS

The particular (technical) approach to the Internet has created business structures that evolved around it, such as expressed in transit and peering relationships of autonomous systems. Any evolution of technologies but in particular any fundamental approach to change the current Internet will undoubtedly have an impact on these existing business structures. Too radical a change will cause problems in adopting the change – and the lack of understanding the proper impact can delay the advancement. Hence, technical and economic migration strategies from *here* to *there* are crucial when targeting a wide adoption of proposed changes. For this reason it is a must the grand challenges in economics to be addressed as well. This needs to start with gathering the right audience for this work and it needs to be driven by a clear emphasis on the concrete problems and the quest for some answers to these.

Regarding social interaction it is common fact that Internet in its early days was a vehicle for both enabling email based communication (reasonably immediate, but not requiring real-time end-to-end connectivity) and for simply improving the information flow between parties, which would have otherwise exchanged the information, but more slowly or in lesser quantities. In addition, along with this beneficial relationship with social structures, it brought as well antisocial opportunities and mis-use. The demands of improving social communication and reflecting social structure are growing but in the same time increasingly issues of privacy and safety in a completely connected world are being addressed. This may follow many possible alternative paths of development. Birth/death records, medical records, banking records and so forth were kept long before there was an Internet, but the Internet not only made them aggregately, but also made it simpler for malefactors to get at them, even attacking the infrastructure itself. It was only as the infrastructure became increasingly integrated into, and critical to, our society transformed now in digital society that attacking it also became increasingly worthwhile.

In that context it is important to be understood that Internet is a reflection of society, but this reflection is always a partial. As such, it will evolve to provide increasing aspects of social infrastructure requirements, but it is unlikely the prediction where the next step will be to be accurate. In fact, some of the innovation comes from other quarters. Who would have thought that carrying around small wireless cell phones with tiny keyboards would turn into instant messaging and from there make the leap to the Internet and soon into all the different modes of social networking with the user designed Web 2.0 tools? Hence, innovation will always have an element of surprise for some stakeholders in society.

One of the interesting social challenges the user community is facing to is the information overload. There is too much information. There are too many services that want to claim the user trust. There are too many options and too many individuals who want an attention. A challenge will be to evolve approaches that reflect the human and social approaches to dealing with overload. This is already happening in what are probably simple ways in social networking contexts. Users group the friends; create channels for topics, create wikis, follow the friends via twitters and so forth. The world is being actually clustered, but this can be understood as the early stage of the social change induced by the Internet. Newspapers were a mechanism for filtering, organizing and limiting information that otherwise would overwhelm the reading audience. With the demise of newspapers, what elements of the almost infinite flow of bits will bring order that is reflective of the human mind and human social structure? In the longer run, will that also allow each of the humans to retain a somewhat personal view in large social structures? How will the individuality and privacy be retained?

Next question to be answered is the impact of the governance on the Internet or vice versa: what is the impact of Internet on the governance. It is clear that the low-cost and pervasive availability of a uniform communications substrate has had an immeasurable impact on the global society that is becoming digital society. Historically explorers circled the world and laid claim on behalf of their home countries to other lands, thus beginning the political and economic connectedness around the globe. The presence of the Internet has qualitatively changed the nature and degree of that connectedness. In the current economic and political situation, no country can make decisions that will have only a local effect. There is no more isolation. Given that, the relationship between the *Internet* and *governance* is becoming even more important. Perhaps even more importantly is the possibility Internet to change forever governance of, by or for a people. Blogging and cell phone cameras that can transmit photos are having profound effects on the capability of individuals to constrain their governments at times when the governments may not want that. This is likely to have an impact on, e.g., regulation when considering a growing role of end users in the participation of the Internet, i.e., end users potentially grow into an essential part of the Future Internet, moving away from their current pre-dominant role of a mere consumer. How this will affect ways to regulate certain parts of the Internet will be important to understand.

VII. NEXT STEPS FORWARD

The most important observation of the EIFFEL Think Tank is that the future architecture to should not be a balance at design-time towards the wanted world, instead minimum substrate should be designed that allows the Internet flexibility to behave in different ways at different times and in different places depending on the outcome of market selection and social regulation mechanisms [19], [20] whilst retaining levels of performance that render it fit for purpose. Hence the research should move from a largely design time to a largely runtime model for resolving potential tussles. Some of them as identified by the EIFFEL Think Tank [3] can be:

- **Resilience, failure tracking & management**: The Internet's distributed design is popularly renowned for its robustness to failure. Indeed failures often do heal automatically, but not quickly. The result is an increasingly unreliable service. Also many failures are not amenable to automatic solution, being due to human errors in configuration and so forth. It is generally believed that the Internet as of today does not have effective solutions these problems.
- **Availability & robustness to attack**: The Internet is continually being used as the means for malware to attack both services and the Internet infrastructure itself. Solutions to these problems often block innovative legitimate uses of the Internet as well as illegitimate ones, effectively slowing down the Internet's evolvability. Proper architectural support to address the root means of these attacks is needed, but there is no consensus between the contending partial solutions.
- **Information security scalability**: The state of the art in information security techniques is sufficiently robust to assure any form of security, except that the techniques do not scale to global proportions in non-hierarchical groups. Another aspect of information security is that of information accountability. While the Internet can cause information to be shared or not, once it has been shared at all, any control is essentially lost of any further sharing and exposure and are dependent on some vague sense of trust in those with whom we have shared.
- **Resource accountability**: The Internet architecture allows everyone to use any resource anywhere on the Internet to the extent that they want. However, at present, network operators are deploying boxes to limit or block communication with certain users or by certain applications. Even if the Internet networks were trying to share the capacity without making judgements about content, the architecture does not reveal the information they need to make other networks and their users accountable when they are over-using stressed resources. The consequent inability to properly limit free riding (or to deliberately allow it) leads to uncertainty over whether capacity investments can be recouped, which in turn negatively affects the whole value chain of the Internet.
- **Network-application coordination**: Over the years, the application programming interfaces (APIs) at the top of the TCP/IP protocol suite have become ossified and stale, but more importantly they have become almost impenetrable. In the downward direction, middle boxes (e.g., firewalls and network address translators) only recognise those protocols that existed when they were deployed. So they block out all attempts by applications to use new APIs to new lower layer protocols and services. In the upward direction, applications cannot find out about the network or their paths through the network in order to create richer services themselves—services that could exploit knowledge of network topology, network failures or traffic characteristics.
- **Scaling for more extreme dynamics**: The dynamic range of the Internet architecture is hitting its limits. For instance, increasingly the inter-domain routing system cannot converge quickly enough following a change, leaving longer periods of disconnection. More sites are connecting to the Internet through multiple links to improve resilience, but the inter-domain routing system is designed so it then has to treat these sites as distinct networks rather than as stubs off a single-provider network. This makes the routing system appear much larger without the Internet growing at all. Also the Internet's congestion control mechanisms have hit the end of their dynamic range since higher bit-rates require higher accelerations to reach them.

By trying to see into the future through debates such those taking place on the Fipedia site a value judgement with respect to the current identified and potential (possibly unidentified) tussles could be the best approach for choosing a particular evolution path for perhaps technical, moral, ethical, legal, or business reasons. The nature and impact of this choice, however, need to be made explicit as well as understood. Since such choices are inherently constraining, the establishment of an orthodoxy that results from making a constricting decision must be balanced by inviting challenge and weighing evidence. For this, it is most important to pay attention in addition to the identified tussles to the evolutionary mechanisms of the Internet—the aspects that determine how evolution progresses and if it progresses at all. Decisions made at this point must remain relevant and fresh for at least as long as the current Internet has proved valuable, in a world, in which Moore's law continues to apply. Investment of time and effort in widespread changes to the whole system will not occur unless such changes both deliver in the timescales needed for cost recovery and continue to give returns over many decades in a constantly evolving technological, economic and societal environment. Along this line, the EIFFEL think-tank has still intention to stimulate, even provoke discussion on the major points of why and how the world will be going about the Future Internet.

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