Scope of Proposed Internet

Uppe Nanaji, V. V. R. L. Sastry

Abstract*— *The Internet is the most important information exchange means nowadays. It has become the core communication environment, not only for business relations, but also for social and human interaction. Yet, the immense success of Internet has created even higher hopes and expectations for new immersive and real-time applications and services, without guarantees that the Internet as we know it today will be able to support them. The EC Future Internet Architecture (FIArch) group has already identified some of the fundamental limitations of current Internet architecture and some of the Design Objectives of the Future Internet [FIArch]. This is the next step, which contributes towards the specification of the Design Principles that will govern the Internet architecture.

Index Terms*— *Business relations, human interaction, immersive, FLArch,Design Objectives,Design Principles.

I. INTRODUCTION

Design principles play a central role in the architecture of the Internet as driving most engineering decisions at conception level but also operational level of communication systems. Often cited as the corner stone of the Internet design compared to architectures that rely exclusively on modelling, they are not formally defined (using a closed mathematical formulation). Classical telecommunication systems (i.e. legacy voice communication) do not consider design principles and derive their model directly from requirements3. However, when it comes to the design of the Internet, the formulation of design principles is a fundamental characteristic of the Internet design process that guides the specification of the design model. The FIArch group has tried to analyse the design principles of today's Internet and foresee the design principles that will govern Future Internet. Detailed analysis has been performed to minimize as much as possible the subjective component. However, as the environment is changing rapidly, different experts of the group have different views and opinions on both the short term (evolutionary) and the longer term (either still evolutionary or clean-slate) design principles underlying the Internet Architecture , which we try to capture and document.

1.2 Scope and Purpose

The purpose of this current document is to identify and to reach some understanding of the different design principles that we expect to govern the architecture of the Future Internet. This may serve as a starting point and comparison basis for all research and development projects that target Future Internet Architecture.

Manuscript Received on December 2014.

Dr. Uppe Nanaji, School of Computing, MEKELLE University, ETHIOPIA.

V. V. R. L. Sastry, Department of Computer Science Engineering, JNTUK, Sri Vasavi Institute of Engineering & Technology, Kanuru, Near Tanuku, W. G. Dt, A.P., India.

We define as ***"architecture"*** a set of functions, states, and objects/information together with their behavior, structure, composition, relationships and spatio-temporal distribution4,5. The specification of the associated functional, object/informational and state models leads to an architectural model comprising a set of components (i.e. procedures, data structures, state machines) and the characterization of their interactions (i.e. messages, calls, events, etc.). Please note that the canonical definition of architecture includes the principles and guidelines governing their design and evolution over time. ***"Design principles"*** refers to agreed *structural & behavioural rules* on how a designer/an architect can best structure the various architectural components and describe the fundamental and *time invariant* laws underlying the working of an *engineered artefact*.

- By ***"structural & behavioural rules"*** *we* refer to the set of commonly accepted and agreed rules serving to guide, control, or regulate a proper and acceptable structure of a system at design time and a proper and acceptable behaviour of a system at running time.
- ***Time invariance*** refers to a system whose output does not depend explicitly on time (this time invariance is to be seen as within a given set of initial conditions due to the technological change and paradigms shifts, the economical constraints, etc.). Robustness and longevity over time is a consequence of this time invariance.
- ***Engineered artefact*** is an object formed/produced by engineering.

One of the critical points that we have faced many times during our analysis has been the term "***complexity***". There are multiple definitions of the complexity.6 Within our analysis we have mainly focus on the *architectural* and *communication* complexity. Moreover, we define the following terms being used throughout this document:

- ***"Communication"*** the exchange of "data" (including both control messages and "data") between a source and a sink.
- **"*Communication end-point*"** the physical or logical source and sink of information. The communication end-point can be considered to be an application, a service, a process, a protocol, a node, a network.
- "***End-to-end communication"*** a communication that takes place between communication end-points of the same physical or logical functional level.
- ***"Module"*** is a unity that represents functions. It could be considered as a physical or logical unity.
- **"Security"** is a process of taking into account all major constraints. Security includes: Robustness, Confidentiality and Integrity.

- ***"Robustness"*** degree to which a system operates correctly in the presence of exceptional inputs or stressful environmental conditions. [IEEE-610]
- ***"Confidentiality"*** is the property of "ensuring that information is accessible only to those authorized to have access" and is one of the cornerstones of information security [ISO-27002].
- ***"Integrity***" In literature there are multiple definitions of the integrity. Here we consider mainly the "***data integrity***"7 and "***system integrity***".

II. EVOLUTION OF EXISTING PRINCIPLES

In this section we highlight design principles that apply to current Internet and we believe that they should be preserved also in the future architecture of the Internet. Other principles should be adapted or augmented.

2.1 Heterogeneity support principle

Heterogeneity at the applications, services, terminals, network topologies and characteristics significantly complicates Internet operation. As a result, one of the major high-level objectives of the Internet is to "leverage and evolve information and communication technologies as well as capabilities and services to fulfil increased quantity and quality of Internet use considering the requirements from an increasingly heterogeneous set of applications" [FIArch]. In the future, the heterogeneity is expected to be much higher than today. Multiple types of terminals/hosts, multiple network nodes, multiple protocols, and multiple applications will exist. Hence, the capability to support **heterogeneity should remain as one of the main design principles.**

2.2 Scalability & the Amplification Principle

The number of devices with Internet access (e.g., PCs, laptops, mobile phones/smart phones, PDAs), communication nodes (e.g., home, access, edge and core routers), autonomous systems, services, applications in the Future Internet is expected to significantly increase. Moreover, the direct interconnection of the sensor networks with the legacy Internet will exponentially increase the number of Internet nodes. If one sees the Internet currently comprising three level of tiers, extension of the Internet at its periphery could expectedly lead to a fourth tier which would have a fundamental impact on the properties of the routing system. As a result, we believe that ***scalability is among the major design principles that should govern Future Internet, while the amplification principle would definitely remain.***

2.3 Robustness principle

In the future, the Internet is expected to handle mission and time critical applications, related with health, energy, transport and financial transactions. On the other hand, the Internet progressively replaces existing application specific networks (e.g. broadcast networks) and other communication medium from newspapers to postal mails -- uniformitarian of the communication medium -- it becomes critical to ensure its robustness (otherwise the decrease of diversity in communication medium may amplify the impact of bug occurrence). As a result, part of the robustness principle that covers issues related to minimizing the malfunction, uninterrupted operation and interoperability, remains unchanged.

2.4 Loose Coupling principle

Loose coupling appears to be a necessary condition for a wellstructured system and a good design as: i) it simplifies testing and troubleshooting procedures because problems are easy to isolate and unlikely to spread or propagate, ii) combined with high cohesion, it supports the general goals of high readability and maintainability, and iii) it minimizes unwanted interaction among system elements. In addition, tightly coupled systems are likely to have unforeseen failure states (as complex interactions permit more complex systems to develop and make the system hard to understand and predict) and implies that the system has less flexibility in recovering from failure states. For these reasons this design principle shall be preserved in Future Internet and even reinforced. Nevertheless, recent evolution shows that loose coupling can also increase difficulty in maintaining synchronization among diverse components within a system when a higher degree of element interdependence is necessary. Hence, it would be appropriate to consider that under stress conditions, higher cohesion should be possible for proper functionality. Grading coupling level at running time could be considered as a mean to circumvent this problem. ***it is fundamental to prevent propagation and that each system keeps its own choice as last resort decision, and become "conservative to what each system accepts and adopts".***

2.5 Locality Principle

The locality principle has played a very important role in computer design, programming and the Internet the last decades. Following the principles of spatial and temporal locality, M.Wilkes introduced in 1965 [Wilkes65], cache memory fulfil the speed gap between the CPU and main memory. Based on this concept, recent advances in computer systems engineering have pushed cache memory to higher levels in the computer systems but the essence remains the same: reflect the chosen methods for using the principles of spatial and temporal locality. In this context, the principles of spatial and temporal locality will have to be extended to distributed computing systems and to the higher layers space of distributed application architectures. On the other hand, locality will play a fundamental role in self-stabilizing distributed systems by ensure sub-linear stabilization with respect to the number of local system components and interactions among components. As a result, we believe that the ***locality principle is important and should be preserved, while its scope should be extended to cover additional roles in distributed systems and distributed application architectures.***

III. PRINCIPLES THAT SHOULD BE AUGMENTED (ADDITION TO THE EXISTING DESCRIPTION)

In this section we highlight design principles that have been described and apply to current Internet but we challenge that they should be augmented or extended.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

3.1 Polymorphism principle (as extension to the modularity principle)

Polymorphism (ability to take on different forms) in computer science/programming space applies to data (generalized data type from which a specialization is made) or functions (function that can evaluate to or be applied to values of different types). It enables to manipulate objects of various classes, and invoke methods on an object without knowing that object's type. Henceforth, the introduction of ***polymorphism would enable the same abstract and autonomous loosely coupled components/objects to have different functional and non-functional behaviour under different environments or circumstances.***

3.2 Unambiguous naming and addressing principle

As stated in RFC 1958, the Internet level protocol are and must independent of the hardware medium and hardware addressing. This approach allows the Internet to exploit any new digital transmission technology of any kind, and to decouple its addressing mechanisms from the hardware. It allows the Internet to be the easy way to interconnect fundamentally different transmission media, and to offer a single platform for a wide variety of Information Infrastructure applications and services. In the future, it is foreseen that not only the end-points (ID) and their attachment points (LOC) need to be unambiguous and unique within the scope in which they appear and are used, but the data and the services, as well. At the end, in most cases, the user is not willing to access a specific server, but the content or the services that this server hosts or offers. If exactly the same data (e.g. content, type, quality, security,) and/or service (i.e. functional and not functional matching) can be provided in another way (e.g. from another server or method), it is also acceptable and in many cases even preferable if the actual quality is better (or cost lower). In Future Internet, naming and addressing as a design principle should be ***extended to unambiguous identify hosts, resources, data, services.***

3.3 Extending the end- to- end principle

Historically, the "end-to-end principle" has been one of the most controversial issues in the Internet innovation. Many experts in the area insist that the "end-to-end" principle is still valid as it applies as the communication is divided at autonomous legs. However, the clear definition of communication end-points becomes more and more complex to delimit, as middle boxes and application layer gateways are deployed at the edges of networks. Finally, as stated in the [FIArch] and further analyzed in [RFC6077], support of congestion control cannot be realized as a pure end-to-end function: congestion is an inherent network phenomenon that in order to be resolved efficiently require some level of cooperation between end-systems and the shared communication infrastructure. Instead of placing specific functions in specific positions—either in end systems or routers in the network core—services and functions must be allowed to be deployed anywhere they are needed [RFC3234]. As a result, we believe that ***motivations to "update" or augment this principle increase; however even if this principle is challenged, due to the heavy consequence in terms of scalability, survivability and robustness on the Internet at large departing from this principle remains open.***

IV. SEEDS FOR NEW DESIGN PRINCIPLES

So far we have presented design principles that should be preserved, adapted or even augmented. Yet, we believe that the Internet Architecture will evolve from a network architecture to a complete communications' operational ecosystem, which will be extended to capture resources of any type (any type of network nodes and their subcomponents and supporting services, any type of network enabled services and any type of content or information) and be extended to even socio-economic dimensions. To realise such Internet Architecture ecosystem requests design principles that go well beyond the networking and primitive services aspects. In this section, we introduce seeds for completely new design principles that may apply to the evolution of the Internet Architecture. A seed for a new design principle refer to a concept or a notion at the inception of a well formulated design principle. The term seed acknowledges that i) formulating principles is a complex exercise, ii) research is still ongoing in proving their value and utility (some of our analysis and exploitation of research results may not be mature enough) but also impact, and iii) the proposed seeds may not be flourishing (a lot of proposal came in and very few will materialize).

4.1 Resources Awareness

Each layer of the FI architecture should be a self-aware and self-managed set of services that works in isolation to provide specific functionalities along with quality guarantees, but at the same time it must cooperate with the others for enabling a holistic service provision.

Cooperation modalities should be defined in order to:

1. Guarantee that each level is aware, at a certain level of abstraction, of the effects on the levels above of achieving or not its guarantee, and
2. Allow each level to negotiate and agree certain guarantees with the levels below.

This service awareness of the infrastructure as a whole is expected to benefit service delivery and allow for higher levels of interactivity. Moreover, network operations based on the lower levels (e.g. routing) will benefit from being able to understand services as first order abstractions, and to optimize their behaviour according to them. This principle is strongly related to "**modularization** by layering", and should complement it by specifying requirements on the functionalities that each module exposes for supporting cross-layer cooperation. Furthermore, applying this principle in combination with the "**loose** coupling" one, will allow for understanding and evaluating the effects of cross-layer awareness and cooperation, in order to avoid or minimize unwanted interactions and non-linear effects. Another principle that needs to be considered refers to "**locality**". Given the need to reduce the distance from a process (i.e. service) to the corresponding data, service awareness will contribute by allowing the development of delivery models (applied both to services and data), being enabled through self-management and cross-layer cooperation approaches.

4.2 Dependability Logic

In future, large-scale Internet-based service deployments, the current and contemporary issues beneath it encountered by consumers will and must be tackled. Indeed, with the current design of the Internet:

● Services are not a "cure-all" and are not cognisant of end-user expectations and needs,especially for enterprises and mission critical applications. Moreover, if existing, grade of service are often static, lack of flexibility and not negotiable. Often it is left up to the users/clients to implement their own systems to ensure the service performs as expected.

● Services operate on a "best-effort" basis. Indeed, in certain parts of a service stack there is little or no comprehension of performance expectations. Moreover, services are often not accountable towards the end-user.

● Services are modelled prior to their deployment in any environment and according to the aforementioned modelling scalability rules and policies are enforced during runtime. Nevertheless and given that infrastructures are application-unaware, the enforced scalability rules and policies are not always adequate to meet the application requirements in terms of efficiency (e.g., in cases of multi-tenancy), performance (e.g., scaling after a specific level doesn't lead to better performance), etc.

● Dynamic distributed environments ask for control policies able to deal intelligently and autonomously with problems, emergent situations, tasks, and other circumstances not necessarily envisaged at the design time. To address this, ***the design of the Internet including its services must be imbued with the principle of dependability (reliability - accountability – verifiability) including selfadaptation and self-learning capability to cope and learn from changes in the operating conditions.***

4.3 Allow the exchange of information between end- points of different type

In order to both enable the *Design for Choice* principle and address the *Information Asymmetry* problem, we introduce the ***Allow the exchange of information between layers and players principle***, which suggests that ***different stakeholders should be able to provide to others information on possible choices and their preferences***. In this way, stakeholders that are provided this information are able to express their interests, to coordinate their objectives and to align their incentives, if these are indeed compatible; as well as to appreciate what the effect of their choices to others will be. Incentive compatibility between players applies when one player's selfish action implies the improvement not only of his own objective but also of those of the other players. This information diffusion can possibly lead to the so-called *"all-win"* situation, whereby all existing players are better off, at least temporarily. In the long term and if new stakeholders also enter/exit the ecosystem then action is anticipated by the remaining ones. The exchange of information between stakeholders implies a flow of information from one stakeholder to another, and the "processing" by each stakeholder; therefore the *constituent capabilities* of this principle include:

- the exposure of information to a stakeholder,
- the abstraction/aggregation of information to be exchanged.
- the collection of information by a stakeholder,
- the assessment of information by a stakeholder, and
- the decision making.

4.4 Sustain the Resources and Brain Investment

Instead, it is important that the Internet is designed to ***sustain brain investment, innovation investment and resource investment toward a global positive return***. For this purpose, it is fundamental to first recognize here the capability of the Internet to accommodate since so far *new applications communicating over a commonly shared infrastructure* (and it basically because the architecture was not designed with the idea to privilege one class of actor against another). It is thus essential to keep the entry barrier as low as possible and structure the design of the Internet so as to allow various communities and people's involvement by, e.g., steer open applications development but without impeding the genericity, evolutivity, openness, and accessibility design objectives. Over time, the Internet shall thus cultivate the opportunity for new players to take benefit of the infrastructure foundation without sacrificing on its global architectural objectives and design principles. Moreover, the Internet architecture should be able to accommodate and sustain its actors and stakeholders' needs in terms of fundamental capabilities, e.g. forwarding and processing capacity.

V. CONCLUSION

The new demands of Internet can be addressed to a certain degree through incremental infrastructure investment combined with "over-dimensioning". However, analyses have shown that increasing the bandwidth to peta-bps on the backbone network will not suffice due to new qualitative requirements in, for example, highly critical services such as e-health applications, clouds of services and clouds of sensors, new social network applications like collaborative 3D immersive environments, new commercial and transactional applications, new location-based services and so on. Design principles have played a central role in the architecture of the Internet as driving most engineering decisions at conception level but also operational level of communication systems. In this document, the FIArch groups has identified the design principles that we expect to govern the architecture of the Future Internet. This may serve as a starting point and comparison basis for all research and development projects that target Future Internet Architecture.

REFERENCES

1. L.J.Fogel, A.J.Owens, and M.J.Walsh, Artificial Intelligence through Simulated Evolution, John Wiley, 1966.
2. W.Heisenberg, Über den anschulichen Inhalt der quantentheoretischen Kinematik und Mechanik, Zeitschrift für Physik, vol..43, no.3-4, pp.172-198, 1927.
3. J.H.Saltzer,, D.P.Reed, D.D.Clark, End-To-End Arguments in System Design, ACM Transactions on Computer Systems (TOCS), vol 2, no.4, November 1984, pp 277-288.
4. W.Stevens, G.Myers, L.Constantine, Structured Design, IBM Systems Journal, vol.13, no.2, pp.115-139, 1974.
5. "The End-End Principle and the Definition of Internet" Preparatory Process: Working Group on Internet Governance (WGIG), Contribution of Corporation for National Research Initiatives, Prepared by: Patrice A. Lyons (November 10, 2004).