The NOMADS Republic

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Abstract: A vision of the NOMADS Republic, the largest nation on earth, is introduced. The NOMADS (Networks of Mobile Adaptive Dependable Systems) infrastructure is aimed at supporting the functionality of such nation. It consists of all systems that satisfy certain minimum requirements, namely, the ability to communicate and to discover, provide and/or use NOMADS services. The goal of NOMADS infrastructure is to deliver low cost, dependable and adaptive connectivity in intelligent and highly semantic manner, making it possible to enter the age of "subdued computing", where computing and communication converge, but stay out of the way.

Keywords: adaptivity, dependability, interoperability, mobility, nomadic computing, networking, subdued computing

1. Introduction

The NOMADS Republic is the largest nation on earth. It boasts several billions of citizens already, and depending on how one counts, its population could grow from 20 to about 100 billion citizens at the end of this decade. The NOMADS Republic has no borders and its growth cannot be stopped. Anyone or anything who/that has an ID, be it a passport or a telephone number, an IP address or a product number, when connected may become a citizen of the NOMADS Republic. This includes the people (users), the infrastructure and embedded systems (sensors and actuators including electromechanical systems such as robots). The goal of NOMADS (Networks of Mobile Adaptive Dependable Systems) infrastructure is to provide low cost, dependable and adaptive connectivity to support mobility, billing and other basic functionalities and services desired by clients and service providers. The NOMADS infrastructure is ubiquitous but rarely pervasive, it is autonomic and proactive and supports humans without technological aggression, trying to hide or embed technical aspects. The ease-of-use is one of the key goals as well. We call this type of processing “subdued computing.”

The paper includes a concept of the NOMADS Republic and a description of the architecture of NOMADS infrastructure.

2. From NOMADs to NOMADS

The current trends in convergence of computing and communication in computer science can be best described as trying to develop ways for different devices to communicate with each other. We are presently in a phase one could call NOMADs [1] as we, as a society, are creating Networks of Mobile Arbitrary Devices. Much effort is being spent on interoperability, but the key issue, semantics of such interoperation, is rarely if at all addressed. Therefore, we propose NOMADS - Networks of Mobile Adaptive Dependable Systems, an infrastructure which enables not only communication, but intelligent and purposeful behavior of all connected systems. The time has come for creating an infrastructure which possesses basic properties such as Mobility, Adaptivity and Dependability (MAD properties) in broad sense including security and real time
ensuring that every citizen of NOMADS Republic is safe and can rely on services that are being offered.

3. The Roots of the Republic and its Makeup

Historically, nomadism was the way of life of people who did not continually live in the same place, mainly for the reasons of survival. Although the traditional nomadism might be on the decline, the modern nomadism, where people travel extensively physically or in a virtual space is on the rise. Virtual presence and “omnipresent living” by sensing, observing, and controlling processes and events remotely or participating in joint experiments will experience an explosive growth and to accelerate this growth a creation of the NOMADS Republic and its infrastructure is proposed.

Extending the Weiser’s evolution in trends in computing [2, 3], we observe that the mainframe computing, where many people share a computer, is a typical many-to-one mapping, while an era of a personal computer with one-computer one-person represents one-to-one mapping. The ubiquitous computing with again many-to-one mapping is reversed because many computers are assigned to a person.

We call our extension “subdued computing” which is similar to the Internet where “many-to-many” mapping dominates, but goes even further and becomes “all-to-all” (see Figure 1 for details). We consider pervasive and ubiquitous models of computing a bit overbearing and sometimes dangerous and risky to human activities and privacy. We want to provide an environment where humans are in charge and their comfort level is not disturbed. Hence the term subdued computing.

With over one billion users of cellular phones alone who are already migrating to the web, billions of devices (sensors, actuators and terminals) appended to the net, billions lines of code, billions of web pages, many of them unmanaged or unmanageable requires a new order. The complexities are enormous and the methods of dealing with them must be pursued. Our response to this challenge is the NOMADS Republic where each network (cluster, overlay or a peer-to-peer group) focuses on guaranteeing a specific level of quality-of-service and a minimum level of adaptivity. The networks are connected over some type of net (e.g., the web) and sensors, actuators, terminal devices such as PC’s, PDA’s and phones and other arbitrary devices such as webcams, robots, mechanical games are attached to it. The users and devices may be mobile and can control, observe and/or be controlled via the network, be it physical or wireless (see Figure 2).

Our goal is to hide the underlying complexity of software and hardware systems behind the services they offer. It is our understanding that majority of communication in the NOMADS Republic will be intra-system, meaning that systems will communicate with each other without human intervention. Only small percentage of systems will interface directly with human users. Therefore, our focus must be on machine-to-machine interaction, rather than on human-machine interface. We must enable, through the resources of the NOMADS Republic, smooth and seamless interoperation between systems on a much higher scale and semantic level that ever attempted before.

Having said all this, what exactly is the NOMADS Republic?
4. Citizens, Services, Laws, Economy and Social Structure of the Republic

One could argue whether the republic (or a democracy if you like) is the best human-invented social system. While there is no straightforward answer, one has to agree that some of the basic functions of the state are to provide citizenship, maintain law and order, support economy, define social structure and give certain services to the population. Based on the model of a republic we describe the NOMADS Republic, in which entities (systems) having certain properties can participate as citizens. Therefore, our task is to identify the citizens of the NOMADS Republic, describe the architecture, show how population can communicate using services, and introduce a legal system, economy principles and a social structure.
4.1 Citizens

A citizen of the NOMADS Republic can be defined as follows:

A citizen of NOMADS Republic is a system that can communicate (IP) and that can discover, provide and/or use NOMADS services.

From this simple definition, two clear requirements are obvious: communication and service provision. Every citizen should possess M(obility), A(daptivity) and D(ependability) properties. We call them MAD properties. Mobility is ensured by the communication layer, while adaptivity and dependability are ensured by the service layer. An abstract view of NOMADS architecture is shown at the Figure 3.

![Figure 3: An abstract view of NOMADS architecture](image)

4.2 Services

The NOMADS service layer is responsible for interoperation between systems, ensuring adaptivity and dependability properties. Each NOMADS citizen may provide services for other citizens to invoke. Services are the basic communication mechanism in the Republic. NOMADS services must also possess certain attributes.
A trusted service is a service which possesses explicit contract and can be composed with other services with respect to that contract.

A NOMADS service is a trusted service whose internal implementation can be verified with respect to the contract.

The Republic must provide means for service discovery. Certain NOMADS citizen will act as service directories. They will collect contracts from other services. It is inherent to NOMADS service layer to enable each citizen to subscribe its services to one or more directories. However, service layer can also support direct (peer-to-peer) communication with interested parties, in the absence of service directory.

4.3 Laws

In the NOMADS Republic, laws are represented by contracts. We define several types of contracts:

- **type contracts** - defining which arguments a service can accept, and which values it can return.
- **semantic contracts** - defining preconditions, postconditions and invariants for a given service method. Preconditions determine what the client of a service must provide, while postconditions determine what the service will guarantee, if preconditions are satisfied. Invariants are rules that must hold before and after each service invocation.
- **performance contracts** - defining performance attributes of a service, such as worst case execution time.
- **dependability contracts** - defining dependability attributes of a service, such as reliability, availability, replication, redundancy, security, etc.
- **event contracts** - services will be able to expose events to which other services can subscribe and be notified when these events occur.
- **rendering contracts** - needed for front-end services only, when communicating with the human user. Since users will have a variety of devices to interact with other NOMADS citizens, this will enable front-end service to render communication appropriately.

It can be clearly seen that the service layer ensures adaptivity and dependability requirements through the use of contracts.

![Figure 4: Composability of NOMADS services](image)

One of the main advantages of NOMADS is the ability of automatic service composition (Figure 4). Using described contracts we are able to model contracts as mathematical properties of services, enabling us to give them functional treatment independent of the language they are written in. That means that we can derive properties of service compositions. In that way we can
derive new services and behavior that were not originally programmed into the Republic. When working together, citizens can accomplish things they are unable to perform alone. It will also be possible to ask the NOMADS infrastructure managers to locate a service provider willing to perform a specific task by submitting a valid contract. The infrastructure would find the combination of citizens best matching each request and employ them to solve the request.

Why do we need automatic service composition? In an environment that expects billions of citizens with population constantly rising, complexity is becoming a major issue. It is unrealistic to expect that human and machine end-users alike will be able to have interfaces to all available infrastructure. Maintenance and configuration are both very serious issues. Instead, it will be much easier to maintain the Republic if end-users could just clearly state what they need, and the other Republic citizens would help them find the resources they want. In such knowledge-propagating world, service composition or collaboration is essential. Furthermore, several approaches are being investigated based on evolutionary self-learning methods to the solution of this problem, meaning that during their lifetime NOMADS citizens learn who they can collaborate with and how to do it. The other approaches include introducing a grammar for negotiation with verbs representing possible actions (service invocations) and nouns representing objects (parameters).

Besides contracts, another major asset of NOMADS services is the ability to verify internal service implementation with respect to contract. In other words, there must be a way to prove that service can be trusted, that is, it really does what it states in the contract. This requirement has two important consequences: many security and quality of service issues are solved; service reuse is encouraged in a formal manner. For this idea to work, a run-time model of service execution is being developed.

4.4 Economy

A healthy economy is based on available resources, market demand and stable financial system. What does the NOMADS Republic’s economy look like?

Resources are being discovered, fetched and used through service layer with respect to contracts. Contracts can be negotiated in order to determine if there is a certain level of composability.

When a chain of service invocation has been established, key element becomes how to make sure that everything is executed inside a transaction. In the complex layout of events, when many services are collaborating and can produce different execution paths, NOMADS Republic must provide robust transaction and communication mechanism. Several techniques can be used, from replication to checkpointing to ensure this property.

Another big challenge for NOMADS economy are the questions of identity and service billing. In an ideal world, nobody would object on having an ID, and all services would be free. Unfortunately, that is not the way our society works. On the contrary, hardly anybody (except for service and product providers) wants to expose his/her ID to the marketing companies thriving on information on buying and lifestyle habits of users, and services will have to be paid for. Therefore, each NOMADS citizen must be able to assume certain security roles, that will determine its rights and context in which it can invoke particular services. Context managers will be assigned this task. Besides providing a security context, they will give different meanings to contracts, enabling more versatile utilization of services offered. In that way it will be possible to execute the same service in different contexts with different results.
The problem with billing is the micropayment. Although several methods of micropayment have been proposed and some of them developed [6] it is still relatively expensive to charge, e.g., credit cards for micro amounts. One solution is to have providers that offer NOMADS accounts for interested citizens. They would function as NOMADS banks. Citizens would deposit certain amount and use it as required, or even be able to obtain a credit. Another complementary form of billing is prepaid cards issued by some physical entities or by NOMADS banks.

4.5 Social structure

Like every other civilized culture, the NOMADS Republic is governed by non-threatening rules, meaning that citizens must not put other citizens in danger as a consequence of their actions. This is established by contract preservation.

Although all NOMADS citizens are born equal, they can be assigned priorities regarding certain contexts. Again, this is a responsibility of the context manager. Prioritizing can help with deadlocks, denial of service or fault tolerance.

There is one question regarding the NOMADS social structure that still has to be answered. Where do the humans fit in this society? What is their place? In other words, are humans citizens of the NOMADS Republic? Answering this question can be difficult. For now, we are tending to initially remove humans from the NOMADS Republic, in a sense that, when born, a human being does not yet belong to the NOMADS Republic. Only when they interact with other NOMADS citizens, do the humans become part of the Republic itself. A person sitting in Sahara without any device to tap into the Republic is not part of the Republic, while another person asking for the airline service to book a ticket via mobile phone is. Also a pacemaker installed in patient’s heart that communicates with a doctor is definitely a Republic’s citizen while the patient’s citizenship might be questionable. Again, it is all a matter of context. However, this is still an open issue, and a human role in the NOMADS Republic is likely to evolve.

5. Conclusion

Convergence of computing and communication is going to make a significant change in the way we work, live, and understand the world around us. However, it will also change a scientific methodology, the way we perceive the old problems, and solve the new ones. The vision of the NOMADS Republic, with its promise of seamless and intelligent service interoperability, opens many research problems and offers a grand challenge to us all. It might be a stepping stone to a truly friendly, non-evasive subdued computing where humans will regain the power of using the computer systems to simplify their activities and enhance their quality of life without being driven by overloads of e-mails, faxes, and ubiquitous telephones.
References


