

Facing IoT - The New Giant Wave of the Information and Communications Technologies Development

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Abstract

The paper main goal is to systemic analyze an emergent field of the information and communications technologies (ICT), the Internet of things (IoT).

Starting from premises as *the mass proliferation and the „giant wave” of IoT in the larger context of Information and Communications Technologies (ICT) exponential evolution in the Information society (IS) toward Knowledge Based Society (KBS), which penetrates and transform **almost anything**, the paper identified and analyzed the **essential implications/conditions** of IoT development at Earth scale: the main driving factors(DFAC), resources(RES) and challenges(CHA).*

For DFAC, a systemic criteria, generally for ICT evolution and then for IoT development, would be to follow simplicity and essential needs rules when expanding, because despite all expected benefits of any application, especially when large numbers are expected, **negative consequences could refer to Earth resources fading, climate changes (CO₂ footprint at planetary scale), humankind healthy/secure evolution or World social unbalances.**

A special focus is on health, because despite the real amazing achievements IoT could bring, considering the actual ones, we have to watch the IoT development as some products/services and facilities could **directly or indirectly harm humankind healthy evolution.**

For RES and CHA, the technical essential implications/conditions of developing IoT at Earth scale are analized. Here IoT as a Big network of networks, Big Data processing, the survival of Moore Law and power/energy sources were analyzed pointing the corresponding main challenges and solutions perspectives.

Finally, among the big „**Questions**” concerning the main challenges of IoT development, the paper adresses the complex field of educational consequences, concluding on the tremendous influence of IoT/ICT in IS/KBS on humankind evolution and emphasizing **the capacity to optimally use the technological progress (first considering the Internet) and the creative potential – which eventually influences innovation and...ICT.**

Keywords: Internet of things, communications and information technology, , content centric networks, mobile-cloud convergence, climate changes, information society, knowledge based society.

JEL Classification: L63; L86; M15; O13; O33

1. What could hide a giant wave?

We recognize that our question is a little rhetorical, as the intention was to point the high level of uncertainty we have to expect, inherently, from something „giant”.

Anyway, for finding an estimate we have to recall again our best „friend”: the imagination.

Speaking about imagination, how could we forget in this context the Albert Einstein magnificent words: *Imagination is more important than knowledge* (because the last is limited).

This introduction is perhaps too complicated, because we try to identify in this paper some **essential implications/conditions** of developing Internet of Things (IoT) in the larger context of Information and Communications Technologies (ICT) exponential evolution, **after** we have analyzed some important aspects of IoT in our previous papers [2][4][8].

One of the relevant mentioned papers conclusions was the fact that the digital era we live in the Information society (IS) toward Knowledge Based Society (KBS) could be mainly characterized by the ICT driving power, which penetrates and transform **almost anything**.

Now it is easy to understand all the context of developing IoT, as many actual definitions [7][6][10][11][5] consider, more or less directly, IoT as Internet of **Everything**.

This way we came back to our initial question and its obvious answer: something „giant” like IoT has clearly the potential to hide (cover) **almost anything**.

As a matter of fact, for this paper the question point is to focus on the necessary implications, meaning conditions or problems to be solved in order to (optimally) develop IoT at planetary scale.

Of course we are focusing, as we have mentioned above, on **essential** implications of IoT development and we include here the main driving factors(DFAC), resources(RES) and challenges(CHA).

In the same time we have to agree that these three issues could not be approached without some inherent explicit connections with IoT actual status (developing phase), implemented applications/areas and already visible difficulties we have mainly analyzed before [2][4][8].

It is also clear that such a huge and complex process, which is developing IoT at Earth scale, is anyway impossible to be accurately foreseen and this is mainly the case when we point the essential features.

A first difficult issue is to define what is essential, even after we have considered, as a first approximation, three main aspects. Then we have to define each aspect, mainly by identifying some of its subsequent components.

As a minimal systemic approach, we consider that a first observation is necessary, as it is also obvious that our approach for the three „main issues” is very relative and they are not accurately independent.

The goal of this analysis is to provide criteria for a stable/sustainable and optimal development of IoT, taking into account that a chaotic mass proliferation of IoT could generate huge resources consumption and other unpredictable consequences.

Of course, one could say: On Earth there is generally a **free market** economy and globalization is also obvious. So what *about* limits, criteria or selective development?

Here we must recall something *about* **Earth resources fading, climate changes, humankind healthy/secure evolution or World social unbalances!**

Speaking, for example, only about climate changes, the specialists already expressed skeptical opinions on the recent achieved Paris Agreement, which is trying to obtain the maintaining of temperature increase under 2°C until 2100. The details of this skepticism will probably be provided by every season’s weather increasing aggressivity and ... temperature.

In particular, IoT/ICT contribution to CO₂ footprint could become consistent considering „the giant wave”.

As a consequence, a systemic criteria, generally for ICT evolution and then for IoT development, would be to follow simplicity and essential needs rules when expanding, because despite all expected benefits of any application, especially when large numbers are expected, the CO₂ footprint at planetary scale must be carefully analyzed.

Although IoT/ICT products and services are implemented for an immense diversity of areas, the standardization must have an essential role for conformity with technical requirements but simplicity and essential needs rules could be also included.

On the other hand, it is quite impossible to build a rigorous model for a such huge process and that is why we will detail the components of the considered issues as much as possible close to these premises.

Still we have identified [2] the main rule of the driving factors for IoT: to *obtain added value* by processing the collected data, for goals like energy (power, fuel etc.) consumption reduction, health improvement and almost always ... money/resources savings.

Now we add, as a complementary criteria, the well known principle of medicine: „Heal as much as possible, but do not harm!”

So IoT must optimize as much as possible, but without considering a single criteria while totally neglecting/omitting others.

In order to obtain added value, but keeping the risk (secondary effects) at controlled levels, IoT future devices/applications must be „smart”, this way providing the specific difference versus existent electrical/automation devices and premises.

An other systemic approach element is the separation of the there issues in two categories.

The first category (DFAC) is associated with humankind needs and social/political aspects, as the main driving factors of IoT implementation. That is why this will be first analyzed.

The second category, to be presented in the next section of the paper, includes the resources and the challenges we suppose to be (considered) mainly technical, but we agree that this assumption is again a relative true.

In order to identify the DFAC main components, we have inherently to observe, by some examples, the actual tendencies, needs and features of the IoT applications, without repeating the details from [2][4][8], but rather sending, when necessary, to them.

We have already proposed [2] a systematic approach describing the actual main directions of IoT development, but here we have to add for them some possible associated criteria of selection.

The principal direction of IoT applications are focused on collecting and processing data concerning the operation/existence of a „thing”/device in order to optimize that thing/device operation/existence.

The problem is that the actual tendency is too general, as such „things” could include industrial machines, home appliances, cars, toys, animals or ... trees.

Here the associated criteria of selection should provide orders of priorities to be considered for investment and development.

For example, the entertainment industry is now including personal products/services by „assistents” (as robots, games etc.) matching the individual actual emotions/disposition, toys, gadgets for pets etc.

Even in the more „natural” optimization fields, like home appliances, we should analyze whether is efficient/justified or not to extend IoT applications for „everything” (like decorative automatization, air smelling or colour/design variations etc.). Here the criteria could apply for energetic efficiency, but also for cost or security reasons.

The second main direction we identified is focused on individual/human body, in order to collect personal data useful for that person (generally for health, but not exclusively) or for entities interested in person's behaviour.

Here the diversity and dynamic of IoT applications is huge and difficult to be selected by concrete criteria.

Still we can make some pertinent observations, just because the focus is the humankind and the long term consequences, either positive or negative, IoT applications could bring for him.

Because health is always on top, despite the real amazing achievements IoT could bring, considering the actual ones, we have to watch the IoT development as some products/services and facilities could ***directly or indirectly harm humankind healthy evolution.***

For example, ***we have to stimulate applications that leverage health/life improvement, education, creative potential and respect for human/environment values,*** but not the ones which enable the sedentary behaviour, human body invasive or immature devices/procedures, environment pollution etc.

All the above mentioned negative consequences could already be observed or foreseen, as excessive/inefficient automation or immature health/clothes IoT devices are possible.

It is important to also observe that the real concerning is probably not coming from the examples of above „short” list, but from the ones, probably not in a short list, we did not expressed/identified yet.

Among the other fields, along with health, the largest area of all, in fact huge versus all other (including health) will be covered by IoT industrial and commerce applications.

That is why, the aim of „outcome economy” is the expression of the intermediate steps to optimize IS/KBS, as products and services, at most from ICT, which will be designed and implemented to provide specific (customized) results [6][12][14][15][2].

Despite this remarkable feature of customized results (sometimes just because of that, single criteria is probable), the risks of generating undesired consequences remain, considering the large diversity and especially the huge number of applications of IoT at Earth scale.

It is sufficient to imagine what could bring for humankind and generally for the Earth environment, the expected (by 2020) 20-50 billions of IoT devices [19][11][13], from the point of view of consumed resources, data/information collecting/transmitting etc.

Again without claiming completeness, we can add, after the health field, other important fields, like Earth resources/environment or legal conformity (including intimacy or security), we have detailed, as purposes, in[2].

As we already have mentioned that the analyzed categories are not totally independent, let's conclude here the first (even incomplete) category, for continuing the analysis in the next section.

2. Facing Big Networks, Big Data and ... Big „Questions”

The technical essential implications/conditions of developing IoT at Earth scale, we intend to analyze here, are also difficult to define/identify, for a such huge, complex and dynamic process, in the context of exponential pace of ICT evolution on IS way towards KBS [2][4][15][16][18].

Why starting with Big Networks?

It is largely agreed that IoT will be, from the point of view of communications infrastructure, a network of networks.

As we are speaking about more than 20 billions connected IoT devices, either small or big, all together will increase the World Internet at dimensions never foreseen and consequently we will have to face very complex challenges when billions of new sensors will require unique IP addresses.

We have mentioned of course [2] that the extension of IPv6 (replacing IPv4) will provide practically unlimited number of addresses and make the management of networks easier due to auto configuration capabilities, offering too improved security features [11].

IP addresses represent still only a necessary, not sufficient, condition to technically be fulfilled in order to have a functional IoT at Earth scale.

The future Internet challenges, relevant also for IoT evolution, include a diversity of new approaches to be studied and eventually implemented.

Among these Internet approaches we can include Content/Information Centric Networks, Mobile-Cloud Convergence or WiFi-LTE Integration etc.

Everyone of these new concepts could take some pages to be shortly presented, but here the point is to focus on the estimated essential problems/solutions picture, emphasizing the unbalanced categories.

In the case of Internet, a system approach tell us that the challenges are so overwhelming, even without the emerging IoT, considering the actual phase of ITC and cloud computing/services, that despite all the actual research, it is difficult to estimate the real balance problems/solutions foreseen for more than 5 years.

Content Centric Networks could optimize the traffic speed for the ever increasing request of information/data downloads (search for topics – Google type), by introducing „name-based routing protocols” [1].

Although IoT will be deployed in a huge diversity of fixed sensors applications, for performance applications mobile Internet traffic will represent the worst case scenarios.

On this way, the actual tendencies are characterized by searching new strategies allowing to shorten the distances (reducing latency).

Among the most important and realistic approaches toward this goal are Mobile-Cloud Convergence and WiFi-LTE Integration.

These approaches have also the advantage to be relatively easy to implement as they basically combine existing technologies (WiFi-LTE Integration) or needs small/feasible adding to existing technologies (Mobile-Cloud Convergence).

Mobile-Cloud Convergence represents, by our opinion, a prominent tendency/approach of future Internet/ICT, which will have important consequences for IoT too, considering not only the mobile IoT devices but the applications/services that will use fixed IoT devices connected with mobile users like smartphones, tablets, laptops etc.

For instance, in Romania (population under 22 millions), where the broadband Internet performances are prominent for Europe (EU too), the number of SIM cards (by ANCOM-The National Authority for Management and Regulations in Communications) are over 22.7 millions (in 2014, +1,8% versus 2013).

In fact, Mobile-Cloud Convergence is a general concept (an ever increasing „desire”), but some concrete solutiones are already foreseen.

For example, a natural approach is to built **Internet-edges data centers (cloudlets)**, in order to reduce traffic on backbones and also latency by shortening the distances end-to-end [9].

Big Data is an emergent, but very general concept, regarding an ever encreasing challenge of ICT and IS/KBS.

„Very general” means, in the case of Big Data, the fact that there are a lot of interpretations around of these two words.

We also presented [15][17][20], that the emergent „data deluge” is a very serious challenge for IS/KBS, but meantime, the profound and essential significance of the tremendous process of generating data on Earth (think also to Pluto mission!) has been partially wasted.

With other words, today Big Data is often used to express application that deal with a lot of data, fact that is not totally wrong.

Our opinion is that the term which regards the ever increasing amount of data generated in a single application must be different from the generic term for the top/special data flows generated in the prominent World projects (like Large Hadron Collider, climate changes, brain map etc.).

Anyway we have to recognize that the difference between the two generic cases is very dynamic (time sensitive), due to the exponential pace of ICT.

Remember that it took decades to add other projects to the huge computing power needed for nuclear explosion simulations and now we have many similar projects but the computing power figures have radically changed.

The reason we prefer a particular term for the highest data flows generated of ICT is just the essence we foreseen relevant for IoT in this paper.

Here we want to emphasize that a „data deluge”, like top World projects generate and also IoT is expected to do as a whole or by special applications, needs new approaches concerning the data processing, storage and interpretation.

Thus we need adequate strategies and algorithms in order to face the „data deluge”, especially in real time applications, but not exclusively.

Considering these premises, our opinion is that the medium/long term evolution of ICT and generally IS/KBS, including IoT, will have to find new approaches in order to ***optimally use and benefit from the immense volume of data that will be available***.

For IoT, but not only, a special remark must be considered, as it essential to understand that the „self managing” power/services that will be eventually provided by IoT optimization applications do not replace (cover) the ever increasing need for data analysis (now covered by data analytics), information refinement and finally knowledge/decision creation for responsible people/authorities, as we already generally mentioned [17].

An interesting observation we propose for analysis is just about the ***Internet itself, as the biggest ever created source of information/documentation, which will exponentially increase, but is far from being optimally used by the humankind***.

We recall that the data generated in the last 3 years is comparable with all the rest of humankind history. This picture could be incredible, but we recall that estimates for 2020 are of about 44zettaB generated, 7billion connected people and 50billion connected devices [19][11][2][4][8].

Why ending with Big „Questions”?

If all answers would be that simple: Because they never ... end!

Indeed, with all World optimism, we have to agree that our ***Big „Questions”*** never end and this is something natural.

Even the fact that these questions are more and more complex and complicated is natural in IS/KBS, but the unusual comes when we feel that ***their answers*** become too difficult to find!

That is why we have to watch [17] and ***avoid to get to that point of „no return” or „no answer”!***

Perhaps one of the easiest questions (for actual research it is still a nightmare!) is how to continue Moore Law or get similar, as IoT will be one of the hardest consumers of smaller and performant ICT.

If we consider only health, as the most important IoT field (by our opinion that should be the case!), the state of the art ICT (and more) will be needed there.

When we remarked „more” (than ICT) we thought at the most relevant example we give to students pointing the personal smartphone: Here is concentrated almost all the humankind technical and scientific progress, including ICT but adding physics, chemistry, mecatronic, biology etc.

In health IoT the mixture of small performant ICT with smart textiles will get wearable IoT, to mention just the tip of iceberg.

Coming back to the ICT actual „nightmare”, we mentioned in 1988 that this moment of MOS nano-channel fading will come and learning from mother nature „research” will help us [20].

The actual status is still optimistic, as latest research is testing new models of chips which integrate CPU (central processing unit) and memory [3], as one of the most promising new paradigm of future core ICT.

A more difficult big question will rise from the necessity to provide power for 50 billions IoT devices, including those implanted in human body.

We already presented some new approaches of this issue [2], but the good news come mainly from health IoT and are based on human body energy, confirming again mother nature role.

The early solutions, like *Thermoelectric Energy Generators* or *Electric Nano Generators* use body thermic energy or movements and could transmit it directly to the implanted/wearable sensors.

The other IoT applications, from an immense diversity of areas (including mountains, forests, sea coasts etc.) containing sometimes thousands of sensors, must take their energy from environmental elements such as materials temperature, vibrations, light, airflow etc.

As we observed, the chain of big questions is never ending, so we choose to select the most relevant ending, in this paper, on most important issue on long term.

In the tremendous increasing IoT/ICT products and services, for facing all other (mentioned or not) challenges, we consider that ***education is the most efficient and necessary enabler of the optimization.***

It is obvious that education generally have itself a lot of components and driving factors.

We already expressed [15][18] that ICT role in IS/KBS is a fundamental enabler for the humankind evolution and creative potential.

That is why we have to carefully analyze how this role is generally implemented and especially how the IoT „giant wave” could influence this role.

If we only recall the essential role, for their education, of what children see around, then we could notice that the driving factors and development criteria for IoT we have analyzed in the first section must be „amplified”.

The most complex component comes from the processes of design, implementation and use of IoT, where instruction/education of large categories of people are involved at large scale.

Here, the known opinion of Steve Jobs is very relevant: ***Computer programming teach you how to think.***

Still we have to further and deeper analyze the future IoT and notice that if only logical thinking is enabled, the other human features and skills could step by step be reduced.

Perhaps ***the best lesson to learn from the optimization processes associated with IoT is that any application must be systemic optimized (not only custom) and environment implications on long term carefully considered.***

3. Conclusions

Considering the mass proliferation and the „giant wave” of Internet of Things (IoT) in the larger context of Information and Communications Technologies (ICT) exponential evolution in the Information society (IS) toward Knowledge Based Society (KBS), which penetrates and transform **almost anything**, the paper identified and analyzed the **essential implications/conditions** of IoT development at Earth scale: the main driving factors(DFAC), resources(RES) and challenges(CHA).

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RES and CHA mainly refer to the technical essential implications/conditions of developing IoT at Earth scale. Here IoT as a Big network of networks, Big Data processing, the survival of Moore Law and power/energy sources were analyzed pointing the corresponding main challenges and solutions perspectives.

In addition, **Big „Questions”** concerning the main challenges of IoT development address the complex field of educational consequences, with focus on the tremendous influence of IoT/ICT in IS/KBS to humankind evolution, regarding **the capacity to optimally use the technological progress (first considering the Internet) and the creative potential – which eventually influences innovation and...ICT!**

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