Grid Meets The Future Internet (Invited Paper)

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ABSTRACT

Efforts for building the future Internet are currently starting in many countries all over the world. The new efforts encourage all manner of research and experimentation, from incremental improvements of existing network architectures and protocols up to and including clean-slate designs for the future Internet. The key measure for how well the future Internet is performing will be in its ability and efficiency for satisfying the demands from the users. This implies that the future Internet must take into account heterogeneous requirements from myriad applications. Grid computing, thanks to its highly heterogeneous applications, is in an ideal position for providing valuable information about such application requirements.

1. INTRODUCTION

The networking community has recently started working towards building the network of the future, or future Internet. Several efforts are already underway in different parts of the world, including the US [3, 6, 7], the European Union [2, 4], as well as Asia [5]. The goals of these new research programs are very open, in that they encourage all manner of research and experimentation, from incremental improvements of existing network architectures and protocols up to and including clean-slate designs for the future Internet [1].

The future Internet will play an increasingly important role in the whole society, and it is therefore vital that these new designs take into account the needs of the applications which will be run on the future Internet. As the needs of the applications become more heterogeneous, the requirements they pose on the services provided by the network will become stricter and more complex. The success of the future Internet will not be measured in how efficiently it performs in terms of traditional networking benchmarks, but instead in terms of *how efficiently the future Internet satisfies the demands from the users.*

This implies that the key to the future Internet is in the creation of new applications *and* in the development of suitable network architectures and communication protocols which meet the demands of these applications. Whereas the current Internet was originally developed from an architecture and protocol-oriented view, the future Internet needs to be developed from the point of view of the applications and in particular the users.

This paper is structured as follows. In Section 2, we will outline some of the main goals of the future Internet projects. Section 3 discusses why these developments are important for the grid community and why the grid community should take an active role in the development of the future Internet. Finally, Section 4 provides some concluding remarks.

2. WHAT WILL THE FUTURE INTERNET LOOK LIKE?

Since the efforts for building the future Internet are only starting [2,5–7], only few concrete results have been obtained thus far. But by looking at the on-going efforts, we can already see the main directions in which the research is progressing, and we can get a glimpse of the main building blocks of the future Internet.

As already mentioned in the introduction, the key to the success of the future Internet will be in its ability to meet the requirements of the users' demands. For example, a user making a telephone call over the Internet expects the network to provide sufficient bandwidth for the data stream generated by the voice codec and sufficiently low delays and loss rates. When all these conditions are met by the network, the user will be satisfied, since the quality of the call experienced by the user is good. Naturally, the user does not think in terms of bandwidth, delay, and loss, but is only concerned with "am I able to make my phone call with good enough quality?". The challenge in designing network architectures and protocols for the future Internet lies in being able to identify this kind of "implicit" quality requirements and translating them to specific actions by the different network components.

We can also expect that users will want to run many different kinds of applications on the future Internet. For example, telephone applications have already made large inroads, as witnessed by the popularity of different Voice-over-IP-applications, and the future is likely to see more and more video content being delivered over the Internet. This will include not only delivering stored video (e.g., films or TV series) but also delivering live content from popular events, such as concerts or sporting events.

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This increased heterogeneity of applications will be the main driver for the development of new architectures and communication protocols for the future Internet. The network must be able to manage its resources in an efficient manner, while at the same time ensuring that the requirements of the applications are being met in a way which is satisfactory to the users sitting in front of those applications. Note that this is not exclusive to applications with human users; even machine-to-machine network applications and communications have requirements for the network and these requirements must also be met.

Developing network architectures and protocols which meet these resource management challenges is at the core of the development of the future Internet. However, the approach should start from the needs of the applications and the architectures and protocols must be able to fulfill the requirements of the applications and users.

Other important shortcomings of the current Internet to be addressed in the future Internet relate to security, privacy, and attribution. Current solutions for securing the Internet are only afterthoughts, not well-thought built-in characteristics of the network. Privacy and attribution are even more conspicuous in the absence from the design considerations of the current Internet. Naturally, they were not of great importance in the atmosphere in which the current Internet originally was developed, but the future Internet cannot function without these two aspects being covered in a satisfactory manner.

3. GRID AND THE FUTURE INTERNET

From the point of view of grid computing, the developments leading to the future Internet are of great importance. Grid computing applications are by their nature networked and highly heterogeneous. A single grid has several partners who are connected by the Internet, each providing some resources for other partners to use and using resources provided by other partners.

Grid applications place considerable emphasis on authentication and accounting, so that the resource provider ultimately remains in control over her resources. Furthermore, the resources in a grid application are more often than not extremely heterogeneous, not just in terms of differences in computing power and connectivity, but also in their very nature. Resources in grid applications can include scientific instruments and experimental devices, the handling of which is outside the realm of typical network protocols and requires solutions tailored to the device. Such resources may have very specific requirements on how they are accessed, what kind of data they produce, and in general, the notion of "satisfactory service quality" may differ greatly from the traditional network-oriented quality of service point of view.

It is exactly this highly heterogeneous nature of grid applications which makes them especially interesting and important for the development of the future Internet. Because grid applications are inherently networked, the quality they offer is determined by how well the network is able to meet their specific requirements. The heterogeneous quality requirements of different grid resources and applications imply that the network architectures and protocols must be extremely flexible in how they allow applications to specify their requirements as well as in how the network manages its resources in order to meet the requirements of the applications. The future Internet should provide a basis for a multitude of applications, and the key to an efficient and flexible future Internet lies in identifying how different applications use the resources provided by the network. Identifying these application- and user-level demands is therefore a prerequisite for a successful future Internet.

The highly heterogeneous nature of grid computing applications make them ideal candidates for providing different sets of requirements. In order for the future Internet to allow the development of novel applications and foster innovation, the basic architecture needs to be built such that it is flexible enough to accommodate the heterogeneous application requirements. The richer the application pool from which the initial requirements are drawn, the richer the architecture and the protocols will be. Although the goal of the future Internet research is to create a flexible network, the flexibility cannot be achieved without careful studies of what kinds of applications users want to run and what the requirements of those applications are.

It is therefore important the researchers in the grid community participate actively in the efforts for creating the future Internet. As mentioned above, the highly heterogeneous nature of grid applications makes them ideal candidates for analyzing the requirements of applications running on the future Internet.

4. CONCLUSION

In this paper we have provided a brief glimpse at the ongoing efforts for developing the future Internet. We have argued that the metric by which the success of the future Internet will be measured is its ability to satisfy the demands and expectations of the users. In order to achieve this goal, the development must take into account many different application requirements to create a flexible network architecture and communication protocols. Grid computing, with its highly heterogeneous applications, resources, and communication needs, may be in an ideal position to provide such requirements.

5. REFERENCES

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