Winternet – A Swedish Initiative for Advanced Internet Research

A project proposal for the SSF programme
‘Internet and mobility’

4th December 2001 – Version 1.65

Proposers

**Dr. Bengt Ahlgren**  
SICS – Swedish Institute of Computer Science  
Box 1263, SE-164 29 Kista  
Bengt.Ahlgren@sics.se  
+46 8 633 1562

**Prof. Per Gunningberg**  
UU – Uppsala University  
Box 325, SE-751 05 Uppsala  
Per.Gunningberg@docs.uu.se  
+46 18 471 3171

**Prof. Gunnar Karlsson**  
KTH – Royal Institute of Technology  
Electrum 204, SE-164 40 Kista  
gk@it.kth.se  
+46 8 752 1445

**Dr. Olov Schelén**  
LTU – Luleå University of Technology  
SE-971 87 Luleå  
Olov.Schelen@cdt.luth.se  
+46 920 49 14 28
Contents

Annex 1: Proposed research programme 2
  1.1 Area 1: Routing architectures ................................................................. 2
    1.1.1 Introduction ....................................................................................... 2
    1.1.2 State of the art ................................................................................. 3
    Project 1: Scalable and robust routing ...................................................... 3
    Project 2: Router and switch architectures ................................................. 4
  1.2 Area 2: Service architectures and application overlays ......................... 5
    1.2.1 Introduction ....................................................................................... 5
    1.2.2 State of the art ................................................................................. 6
    Project 3: New architectures .................................................................. 6
    Project 4: Application service overlays .................................................... 7
  1.3 Area 3: Self-managed networks and terminals .......................................... 7
    1.3.1 Introduction ....................................................................................... 7
    1.3.2 State of the art ................................................................................. 7
    Project 5: Self-regulating traffic control ..................................................... 8
    Project 6: Self-managed overlays ............................................................... 9
    Project 7: Autonomous security management .......................................... 9
  1.4 Approach and methodology ..................................................................... 9
  1.5 Expected results and dissemination ......................................................... 10
  1.6 Summary of projects and resources ......................................................... 10
  1.7 References .............................................................................................. 11

Annex 2: Proposed budget 12
  2.1 Organisation ............................................................................................ 12
  2.2 Relation with SCINT .............................................................................. 12
  2.3 Swedish workshop in computer networking ............................................. 12
  2.4 Cooperation and joint graduate education .............................................. 12
  2.5 Research personnel ................................................................................. 12
     2.5.1 SICS ................................................................................................. 12
     2.5.2 KTH ................................................................................................. 13
     2.5.3 LTU ................................................................................................. 13
     2.5.4 UU ................................................................................................. 14
  2.6 Programme central costs ......................................................................... 15
  2.7 Programme total cost ............................................................................... 15

Annex 3: Research group survey 16
  3.A Principal investigators and students ....................................................... 16
  3.B Curricula vitae ........................................................................................ 17
  3.D Scientific output .................................................................................... 22
  3.E Present activity and financing ................................................................. 25
  3.F International cooperation ....................................................................... 26
  3.G Industrial contacts ................................................................................ 26

Annex 4: Strategic relevance 28
  4.1 Scientific relevance ................................................................................. 28
  4.2 Industrial relevance ................................................................................. 28
  4.3 Society and educational relevance ........................................................... 28
Annex 1: Proposed research programme

The Internet is evolving with its commercial success and its growth into a truly global infrastructure for use by everyone. This evolution spurs us to conduct research to enhance the Internet architecture to accommodate new requirements [2] that are emerging as a result of its success:

- **More demanding applications**: Applications are more demanding in terms of network predictability, dependability and mobility, often to meet commercial requirements.

- **Security in an untrustworthy world**: The Internet was designed with the assumption that the network end points could be trusted. One result is vulnerability to abuse in the form of denial of service attacks.

- **Scalability**: The size of the Internet infrastructure is close to its limit with current technology.

- **Non-specialist users**: The global infrastructure is not a tool for only specialists. Ordinary people require technology that is easier to configure and maintain.

The overall objective of this programme is to enhance the Internet infrastructure to meet the new requirements, taking advantage of the end-to-end design principle that has been crucial to the success of the Internet. The principle, which is challenged by the new requirements, states that application level functions should not be built into the lower layers of the network, but rather implemented at the end points. The principle results in a flexible network infrastructure that can support new and not yet anticipated applications.

Ongoing efforts to address some of the new requirements within the existing Internet architecture are creating a patchwork of new features and protocols. Research are therefore needed along two paths. The first is to address immediate problems in the current architecture. The second is to conduct long term research towards new architectures that are unconstrained by current practise and standards.

We propose to conduct pioneering research within three overlapping areas that we believe are important for the two paths and for meeting the above requirements. The first area, **Routing architectures**, addresses scalability and robustness problems in the infrastructure, as well as routing performance and real time (QoS) properties. The second area, **service architectures and application overlays**, takes an overall view of the evolution of a new Internet architecture. One goal is to provide an application service architecture that simplifies the deployment of new applications. The third area, **self-managed networks and terminals**, has the objective of simplifying the management of network equipment for both end users and operators. The activities are traffic control, management of the application overlays, and security management including countermeasures for denial of service attacks.

**Central research issues** The three proposed research areas have in common that they address important research issues in the Internet infrastructure, i.e., at and directly above the IP layer. The central issues, which are recurring in different perspectives in the three areas, are **naming and addressing**, **routing**, **mobility**, **security**, and **quality of service**. The first of the research areas is more concrete, while the other two are more visionary.

The general motivation for this research programme is its strategic importance for Swedish industry and society at large to influence the evolution of the Internet infrastructure. We believe that this programme will contribute to keeping Sweden’s leadership in Internet and mobile technology.

This research programme builds on previous research results and the expertise of the proposers. We have gained the expertise during ten years or more of collaborative research in computer networking. We represent the most visible Swedish constellation in international computer network research. The programme will strengthen our collaboration and provide a larger and more vivid research environment than each partner can do on their own.

1.1 Area 1: Routing architectures

1.1.1 Introduction

During the last decade, we have witnessed the tremendous growth of the Internet. IP-technologies are now rapidly becoming de facto standard not only for data communications but also for voice and multi-media. The success has also led to the two major problems facing the Internet today: scalability problems with the routing protocols, and lack of sufficiently fast switching equipment. The first problem stems from an
increasing user population and increasing interconnection of network domains. The second stems from the ensuing demand on communication capacity. We aim at developing a routing architecture that allow the vast IP version 6 address space to be utilised and to build routers that are fast enough to handle the increasing traffic volume with support of a reasonable set of service qualities.

IP routing and packet forwarding provides basic global packet connectivity in the Internet. Routing is the act of applying a distributed algorithm to collect information on network topology and advertised reachability, and from this information make decisions on which paths that should be preferred towards various destination prefixes. The preferred routes are installed in a routing table, which is mapped to a forwarding table for efficient look-up. Packet forwarding is the act of taking addresses of individual packets and looking up the best matching prefix in a forwarding table.

The research proposed in this area addresses many of the new requirements listed in the introduction and provides a foundation for the subsequent two areas. The research problems in this area stem from current technology and imminent problems faced by the core functionality of the Internet.

1.1.2 State of the art

The dominant tool for policy-based inter-domain routing (IDR) in the Internet, the Border Gateway Protocol (BGP), suffers from performance problems induced by the increasing size and complexity of the Internet backbone [8, 12]. Current trends indicate that the Internet is becoming more densely connected at the peripheral leaf areas and that the demand for inter-domain policy control increases.

Increased inter-domain connectivity means that the Internet topology is becoming less hierarchical (due to multi-homing), which poses a problem to current inter-domain aggregation methods. Increasing number of autonomous systems being advertised leads to increased routing table size [10]. The demand for policy-based routing over the alternative paths further increases the amount of advertised reachability information of small leaf networks along various paths into the core of the Internet. This development poses one of the most interesting challenges to the architecture of the Internet. Current research includes determining problems with the current routing architecture and defining requirements for future domain routing architectures [OS4].

Among the requirements is multi-path forwarding. Today, the Internet routing infrastructure does not generally use multiple paths to forward traffic between two points in the network. Instead, the routing protocol selects a single path that will receive all the traffic. The main reason for using multiple paths is to make better use of network resources. At the same time, the network service provided to the users can be improved. NetScope [6] is an example of a tool that performs load balancing. Our own previous work in the area is based on using multi-commodity flow optimisation for load balancing within a routing domain.

The rapid increase in optical link capacity causes routers in today’s communication networks to be bottlenecks. Also, networks are integrating different types of services, such as voice, video, VPN, VLAN, and ordinary best-effort data traffic. This puts high demands on the routers ability to classify and modify the traffic. Other problems for router designers are the rapidly increasing size of routing tables and the need to support new and enhanced network protocols. There has been a tremendous interest within the industry to address these problems by application-specific hardware, often referred to as network processors or NPUs [7]. The first generation was developed for core routers. The problems faced in access routers and the specific needs of mobile networks have received less attention. To build an NPU successfully requires a clear understanding of its application area. Available NPUs fail in many respects: they are hard to program and lack necessary memory bandwidth. Here lies an opportunity for Swedish research, with our strong research tradition in network protocols, data structures, computer architecture, and a strong telecom industry.

Project 1: Scalable and robust routing

Purpose and motivation In the IETF [10], there is a process of finding solutions to scalability and robustness that can be applied in the short-term within the basic BGP specification. These solutions are based on advertising information as a part of standardised BGP objects that can help filtering and aggregating BGP information as it is advertised. In the long term, rather than making patches to the basic BGP specification, efforts will be taken to specify a next generation routing architecture that may (at least technically) be ready to replace BGP in, say, five years. In this process large research efforts are necessary to develop both short-term and long-term solutions and to evaluate and verify these solutions. Besides the

---

1Citations with letters refer to the individual publication lists starting on page 22.
scalability issue, there are new demands on routing protocols to provide robustness and adequate services to emerging applications, ranging from hard real-time communication to large scale content distribution and caching. Potential exhaustion of the existing address space, increasing convergence time, the stability of routing tables entries and the average prefix length of entries in BGP tables are the most severe problems that must be addressed in long term solutions.

Optimisation of the traffic flow in order to automatically load balance over multiple paths is a desired feature of a new long term solution. Adding such a function can however be a tradeoff against the other goals of a new inter-domain routing system.

It should be pointed out that the next generation internet protocol, IPv6, does not include solutions for the above described problems. Rather, the increased number of addresses may exacerbate the scalability problem. Therefore the routing architecture must be developed independent of a particular IP version used.

**Research issues and approach** In this project, we will study and develop new routing approaches to allow better aggregation of routing information. We will develop a scheme for fail-over routing to meet the robustness needs of interactive real-time applications in case of link failures. Slow convergence and even divergence under configured routing policies is a severe problem in inter-domain routing. A goal is to design a new routing architecture and to deploy mathematical analysis to address types of policies that are incompatible across domain boundaries and cause divergence of routing. We will also develop a mechanism that enables load-sensitive use of multiple paths. The mechanism will probably need to work on a rather long time-scale (hours) and within the local scope controlled by one network operator.

**Resources and deliverables**

*Resources:* LTU 2.5 man-years, SICS 1 man-year, KTH 0.5 man-years

*Deliverables:*

1-a Provide proof of expected undesirable properties of BGP and a proposal for changes in a model of BGP.

1-b Build a simulator and test different methods proposed by researchers through simulations on models of future domain routing protocols.

1-c Creating a model meeting requirements for IDR and provide a specification for future IDR, based on the model.

1-d Design and evaluate a mechanism for flow optimisation for a future IDR system.

**Project 2: Router and switch architectures**

*Purpose and motivation* The intention in this project is to study the functions, architectures and implementations of network nodes. The rapid increase in optical link capacity causes routers in today’s communication networks to be bottlenecks. Also, networks are integrating different types of services, such as voice, video, VPN, application overlays, and ordinary best-effort data traffic. This puts high demands on the routers ability to classify and modify the traffic. Other problems for router designers are the rapidly increasing size of routing tables and the need to support new and enhanced network protocols. Thus, the sheer scaling of the Internet with respect to service offering, address space and traffic volumes is enough to motive the research on faster and flexible router architectures.

*Research issues and approach* The main functions that a router performs to forward packets are to lookup the IP address to determine the output port, schedule packets from different inputs that are destined to the same output, and to switch them from input to output. We have developed a very efficient software address-lookup algorithm and intend to investigate its implementation in hardware and to generalise it for multicast, quality-of-service based routing, mobility and multi-path routing [GK1].

The scheduling to resolve output contention should maximise throughput and meet quality criteria for the traffic. We have developed a decentralised contention resolution algorithm that operates in stages with local information [GK18]. It avoids all scaling problems of centralised schedulers. The algorithm must be studied further with respect to quality of service. A network processor could beneficially do the packet handling in the fast path that most packets take. We intend to design a router based on such processors, and will also study the processor architecture and the requirements placed on it by various network types [14]. One particularly interesting research topic around switching is to determine how the impressive developments in optics could be used for switching [GK10], [9]. In general the problems with designing and building optical packet switches stem from the difficulty to buffer and process light signals.
The research outlined above is based on a traditional view of switching, namely forwarding of packets based on addresses contained in their headers. The research is thus aimed at the efficiency for performing that function and not at the function itself. We will, however, also look at switching more generally.

An important and growing area is session switching, also called 4/7 level switching. The output port is here determined by a combination of application port identifiers and the content of a packet/session. Firewalls and web proxies are well known variants. For application overlays and content distribution networks there is a desire to route sessions to the most efficient end-point depending on the content. We propose research into efficient switching architectures that supports application overlays (see also Project 4 on application service overlays in this proposal). The research builds on our previous research on dynamic proxy set-ups [PG3], content admission control in webservers [PG2], and extensible routers [PG1]. Our research will include how to handle session state and how to consider other constraints for session switching such as mobility, policy, and load balancing.

Active network is the name given to a network that can be dynamically changed by program code included in the packets. It is a generalisation of the addressing concept in that the functions applied to a packet in a switch are determined by the code the packet carries. We have previously and successfully used active networking techniques in ad hoc routing, where the infrastructure is rapidly changing [16].

Resources and deliverables

Resources: KTH 2 man-years, UU 1 man-year, LTU 0.5 man-years

Deliverables:

2-a The router architecture will be laid out coarsely and specific functions will be targeted from the start: Continued evaluation and development of the address lookup algorithm. The scheduling will be studied with respect to performance and further design.

2-b Study of network processor architectures for use in ultra-fast, multi-service, session and active-network switches. Will last for full duration of the project.

1.2 Area 2: Service architectures and application overlays

1.2.1 Introduction

The Internet is changing with its commercial success. An important factor for the success was the ability of existing Internet protocols to scale the infrastructure to a truly world wide and pervasive network. The end-to-end design principle states that application level functions should not be built into the lower layers of the network, but rather implemented at the end points. This has been crucial for scalability because it separates the data transport from the application services. This architectural design keeps the basic network infrastructure in the form of routers and switches simple and efficient. It also releases the innovative power because virtually anyone can offer application services, not just network operators.

The end-to-end principle is now challenged [2] by the new commercial requirements. The ongoing efforts to address the requirements are creating a patchwork of new features and protocols that do not follow the end-to-end principle, and that sometimes are mutually incompatible. It is no longer the research community that is shaping the development, but rather the commercial interests. The result is that problems are solved within a narrow scope and that no one takes responsibility for the overall architecture. The challenge for networking research is therefore to both address problems in the current Internet architecture, related to the new requirements, and to also conduct research towards new architectures that are unconstrained by current practise. There is a need to revisit the principles behind the Internet architecture to meet future demands and not yet anticipated applications. In this research area we propose two projects with this purpose.

An architectural concept that harmonizes with the separation of services and data transport are application overlays. Such overlays use interconnected end-points to provide a service. With the increased capacity of backbone links, it has become attractive to provide compute server farms at strategic points inside the backbone network, e.g., at GIX points\(^2\). From the protocol architecture designer’s point of view, these farms are not part of the network. But from the application service provider’s point of view, they are strategically located inside the network and can be used to support enhanced services. An example of using compute servers is caching of web pages. These cache servers deal with content, i.e., web pages, rather than network packets. From content provider’s and user’s point of view, the caches create a content distribution network, that is an overlay on the physical network. The set of cache handling services: replication, synchronisation, and data transfer between caches, define a specific service architecture for

\(^2\)Exchange points between Internet providers.
building network wide caching services. Several other application overlays exist or are emerging although they are not explicitly identified as overlays. Examples are music distribution like Gnutella, chat programs such as ICQ, and IP telephony. The content distributed in these overlays are, respectively, music files, messages and audio streams.

1.2.2 State of the art

Concerns have recently been raised that the range of new requirements could compromise the original design principles of the Internet architecture [2]. A recent proposal by Braden et al proposes a focused research effort to develop a next-generation Internet architecture to meet this concern [3]. There exist several recent research results that aim at major architectural changes of the Internet, in particular to the addressing, naming and routing principles, e.g., TRIAD, Oxygen and SAHARA. These three principles are also in the center for peer-to-peer application overlays.

The earliest and most common overlays are virtual private networks, VPNs, ensuring secure data transport services between end-points. Note that application data is transparent to VPN:s. Several tools exist for creating such overlays, and overlays on overlays, e.g., X-Bone [15]. Much of the recent research on application overlays focus on support for peer-to-peer file sharing. Tapestry, Pastry, CAN, and CHORD are recent efforts that all suggest their own naming, address and route look-up mechanisms that are scalable and efficient. Besides these mechanisms, some of them deal with the membership problem; who is attached, how to attach and how to handle members that leave orderly or silently [13]. Coupled with this is the robustness and reliability provision [1]. While these ongoing overlays focus on naming, addressing, and robustness we intent to go one step further and study other additional mechanisms including quality of service and the provision of different levels of reliability. The proposed research builds on our experiences of creating dynamic content adaptation networks [PG3,PG4], providing IP telephony services [BA2] and QoS brokerage [OS2,OS8].

Within the EU LTR project HIPPARCH, UU and SICS have conducted important previous research on high-performing communication protocol architectures based on the application layer framing and integrated layer processing concepts [BA5,BA6,BA7,BA8]. The same two partners are involved with related work within the SITI project I3/Connected on spontaneous networking [BA1], which raises the issues of naming, addressing and routing.

Project 3: New architectures

Purpose and motivation In the last ten years we have seen the Internet growing from a network for researchers into a global information infrastructure. This development is a great success for computer networking research. There is however a downside with the success. Many new research ideas and proposed solutions to real problems are dismissed a priori because they can not be realised in the current Internet, which is constrained by current standards and high costs to change the large installed base.

In this project we will conduct research towards new architectures that are unconstrained by current practise. The purpose is to take an overall view on the evolution of the Internet architecture.

Research issues and approach This project acts as a ‘think tank’ for new ideas that emerge from the other projects in the programme. The ideas are put into context of and contribute to an evolving Internet architecture. This project thus complements other projects in the programme. One part of this effort consists of seminars and workshops. In addition, we propose concrete research concerning naming and addressing, in particular the separation of routable addresses and unique endpoint identifiers for mobile nodes. The progress of the ‘NewArch’ project [3] is one topic of the seminars. We intend to establish a relationship with the NewArch team, starting with an invitation to present their ideas at the annual workshop which we will arrange as part of this research programme.

Resources and deliverables

Resources: SICS, UU, KTH, LTU, total 2 man-years

Deliverables:
3-a Arranging national seminars with SCINT on “New Internet Architectures”.
3-b Discussions with invited speakers at the annual workshop arranged as part of the programme
3-c Publication on and demonstration of a new naming and addressing architecture
Project 4: Application service overlays

Purpose and motivation  It is likely that distributed applications, spanning from tiny networks and to the whole Internet, will use overlay abstractions. Although the existing overlays are application specific, there is a set of services that are recurring in many of them. Besides naming and addressing conventions they include: authentication and security, notification, content searching, performance and reliability demands, content adaptation to terminals, debiting/billing, redirection and group communication.

Most of the existing overlays builds on specific standards (sometimes de facto standard protocols) and some on proprietary protocols for providing the application specific services. In the best case they work well, in other cases they are inefficient and in the worst cases they do not provide desired services since the underlying network architecture do not implement the necessary abstractions.

Some services for overlays are hence best provided by enhancing the existing IP layer. They include: QoS, mobility, wireless link issues, localisation services, debiting of bandwidth, performance monitoring, bandwidth brokerage, provision of different traffic classes, and availability/reliability services.

Research issues and approach  In this project we will design protocols and tools for services that are common to overlays. In our approach we will first identify the common set and then focus on a few of them, building on our previous research. To show feasibility we will select one or two applications and demonstrate the benefits with experiments. Voice over IP is a strong application candidate. For IP networks to support interactive real-time streams over heterogeneous (i.e., partly resource constrained) networks, there is a need for research on methods for performance measurement, admission control and network provisioning. This can be supported by resource management infrastructures [OS10].

The outcome is expected to be session protocols, look-up servers, service brokers, tools for load balancing/reliability and distributed platforms that directly can be used to build content distribution networks and to better support overlays for interactive real-time communication. Our contribution will be in the border between the network and applications layers.

Resources and deliverables

Resources:  UU 2 man-years, SICS 1 man-year, LTU 0.5 man-years
Deliverables:
4-a Report on Identification of common overlay services
4-b Tools and protocols for overlay architectures
4-c Demonstration platforms

1.3 Area 3: Self-managed networks and terminals

1.3.1 Introduction

As the Internet grows, the diversity of the Internet increases in several important respects. The diversity of network characteristics increases, not least by the rapid deployment of wireless networks and mobile nodes. Mobility will not only mean that nodes move, but also that networks form and dissolve in spontaneous or ad-hoc ways. The diversity of terminals increases as small and embedded devices make their claim for full Internet connectivity. The diversity of users increases as more of the world’s population connects to the Internet.

Given these trends, the installation, configuration and management of networks and terminals will become increasingly complex. The configuration and management of network equipment and end systems is already today one of the costliest aspects of network operations. There is consequently an urgent need to automate many of the issues related to network operations and system configuration. The advantages are more cost efficient and reliable operation since human involvement is reduced, and easier management of those tasks that still require manual intervention. This work area will address these issues in three projects: self-regulating traffic control, self-managed overlays and autonomous security management. Common to all projects is that the self-managed system should assess its state and strive towards a desired state.

1.3.2 State of the art

Self-management is a goal and/or prerequisite of many systems. Two main areas of efforts today can be found in the areas of sensor networks and consumer appliances. In massive sensor networks [4], a prerequisite for a functional system is its ability to configure and manage itself without human interaction. For, e.g., military applications (sensors spread over enemy lines), human management is of course impossible,
but even for friendly environments, the vast amount of nodes makes human management not feasible. For consumer appliances, significant work is being done within the IETF, notably the zeroconf group. For these types of applications, self-configuration and self-management is a goal, but some minor human interaction can still be tolerated.

Network self-regulation is a self-management area of interest. It is by now widely accepted that traffic in the Internet is statistically self-similar. Analysis of queueing systems with self-similar input traffic is being pursued, following the pioneering work of Norros. There is, however, little to be found in the literature on controlling the behaviour of the traffic flows to reduce its variability. There has been recent interest from control theorists to look at networking problems, but mostly at TCP (for instance by Hespahna, Low, Hollot and Mascolo). Kelly [11] has proved some fundamental mathematical properties for distributed network control that forms a basis for the work proposed herein.

At Uppsala university, we have done several years of research on how thin clients are attached to a network and how to configure networks according to dynamic settings. In the MARCH project [PG3] we showed how proxies can be dynamically tailor made to the devices’ form factors, the network characteristics and the user preferences. In the ARRCANE project [16] we have studied ad hoc routing protocols, in particular how an Active Networking approach can be used to learn the topology, the communication pattern, the mobility and to launch the best routing protocol to the situation.

SICS and Uppsala University are collaborating the the SITI I3/Connected project where we study auto configuration in the context of spontaneous networks [BA1]. Small wireless clients is one application area in the project where secure attachment to different media is important.

Project 5: Self-regulating traffic control

Purpose and motivation  In the process industry, feedback control is a widely recognised to increase productivity and product quality. The intention of this project is to explore what control theory has to offer networking. The concrete goal is to develop automatic control mechanisms for reducing the risk for network congestion by smoothing traffic streams in nodes and end-to-end, and for equalise the blocking probabilities with respect to resource reservations.

Research issues and approach The research on temporal controls is divided into nodal control in the network and end-to-end control between the communicating hosts. The former gives traffic smoothing in routers, i.e., adaptive low-pass filtering of load surges to reduce the risk of congestion. We hope that denial-of-service attacks might be alleviated by this nodal load control. The temporal per-node control also includes the allocation of capacity on links for different service classes (see [GK15-16]). The allocation should attempt to equalise the blocking probabilities for reservations over all paths in the network. End-to-end congestion control is used in addition to the nodal control. TCP uses a control rule based on additive increase and multiplicative decrease (AIMD) to regulate the source’s sending behaviour. This rule should be evaluated in terms of optimality. We would ideally like a rule that is tunable to suit different applications’ behaviour (streaming and batch data) and sizes of play-out buffers. We will study the controls both theoretically and through simulation. A promising modelling tool is Modelica (www.modelica.org), which is currently used at KTH S3 to model TCP. The controls will also be implemented in software-based routers and in a prototype TCP.

The work will be coordinated with a project of Hjalmarsson, Johansson, and Karlsson ‘Towards a self-regulating Internet’ (supported by VR).

Resources and deliverables

Resources:  KTH 2 man-years, SICS 1 man-year

Deliverables:

5-a  A complete nodal smoothing algorithm. It will be evaluated in a network setting, and with respect to prevention of denial-of-service attacks (aimed at network resources). This is the first work item that will be completed within one year.

5-b  End-to-end congestion control will be studied in parallel with the nodal control, and will be started towards the end of the first work year. It will deliver a prototype TCP implementation with tuneable aggressiveness, combined window and rate control [5] and other results from the study.

5-c  A capacity allocation scheme for quality-of-service classes. This work will commence during the second year, and aligned to the design of a quality-of-service architecture at KTH.
Project 6: Self-managed overlays

**Purpose and motivation**  In future networks, virtual overlayed networks will be very common. Virtual Private Networks (VPNs) are one important example of how virtual networks can be overlayed upon a physical network. Other examples include peer-to-peer systems (e.g., Gnutella, Napster) that effectively constitute overlayed networks. As emerging architectures for efficient handling of overlays become common, the grouping of nodes, users and/or applications into virtual networks will become more and more common. The complexity increases as these networks are hierarchically overlayed.

**Research issues and approach**  Hierarchically overlayed virtual networks will encounter several complex issues that should be dealt with autonomously. The mapping between overlays must be efficient in order to avoid sub-optimisation of resource utilisation. A straightforward example is physical proximity routing (‘how to find the physically nearest instance of a certain resource’), where proximity in network topology (e.g., two nodes with direct connection) in no sense guarantees physical proximity. Another issue is how conflicts (e.g., contention for the same resource) should be solved or avoided. A goal of this project is to investigate how network overlay architectures should be designed. Our research approach will be that network overlays will need *vertical integration*, i.e., virtual networks must consider other virtual networks (and the physical network) when addressing the issues of resource utilisation, be it on a node, user or application basis.

**Resources and deliverables**

*Resources:*  UU 2 man-years

*Deliverables:*

6-a  Studies of self-managed resource control in hierarchical overlayed networks.
6-b  Design proposals/guidelines for overlay network design.
6-c  Research papers becoming parts of a PhD/Lic thesis.

Project 7: Autonomous security management

**Purpose and motivation**  Security is an increasingly important issue in the Internet. For future, self-managing networks, security management will be even more important, since the networks will operate without human supervision, meaning that all security control and surveillance is left to the autonomous system. Such systems must not only be secure, but also robust enough to withstand security attacks and to recover from disruptions of service caused by these attacks.

**Research issues and approach**  We intend to investigate two important research issues with respect to autonomous security management: denial of service attacks and identification and authentication in massive systems.

Disruption from service caused by denial of service (DoS) attacks is an increasing problem in the Internet. Preventing DoS attacks is critical in order to achieve a robust and resilient network. Three problems that we will address in order to prevent DoS attacks are: prevention of source address forgery, identification of distributed attacks, and neutralisation of distributed attacks.

Identification and authentication in massive systems will give rise to a number of scalability problems. Issues of how trust is shared and spread through massive autonomous networks is important, not only to sensor networks, but to all autonomous networks where mechanisms is expected to scale to large numbers of nodes.

**Resources and deliverables**

*Resources:*  UU 1 man-year, LTU 1 man-year, SICS 1 man-year

*Deliverables:*

7-a  Reports on the automatic detection and prevention of denial of service attacks.
7-b  Reports on automatic management of identification and authentication in massive networks.

1.4 Approach and methodology

Our research method is mainly experimental. We do innovations, theoretical evaluations and practical experiments through simulation and prototype testbeds, as well as measurements in operating networks.
Our objective is to provide both long term speculative research and short term applicable results. Long term solutions often go beyond what can be evaluated in current technology testbeds. They are evaluated theoretically and through simulation. Short term solutions are often created as spin-offs from long term research. Typically they represent an evolution with respect to the constraints of current technology. We stress the importance of quantitative and qualitative evaluation through simulations and measurements in real networks and prototype testbeds. This approach provides tangible results that are demonstrated for immediate industrial benefit together with general results and guidelines for longer term development.

The design and operation of communication systems are highly dependent on standardisation of protocols and interfaces. The widely accepted standards are fundamental to public networking, but also hinder the introduction of new concepts that break with prior art. When setting a far-reaching research agenda, it is therefore important that the imagination is not tied down by issues relating to backward compatibility and interoperability.

1.5 Expected results and dissemination

We expect several types of results from this research programme. We divide them into industry related, classical academic results, impact on education and results for the general public. We intend to work with SCINT to spread our results nationally, e.g., by co-organising workshops.

Academic results

- Publication of articles in scientific workshops, conferences and journals. We have previously been successful in publishing in the most competitive venues.
- PhD and Licentiate exams. Students will perform their thesis work as part of the programme.
- The establishment of a yearly national workshop on computer networks. We have already organised two such workshops among the partners (Sept 2000 and June 2001).
- Demonstration platforms for showing feasibility of ideas.

Industry related results

- Prototype implementations and other artifacts used for simulation and experimental evaluation of the research results. We expect patent disclosures as major results from prototype implementations.
- Participate in and have an impact on standardisation performed in the IETF.
- Seminars for the industry.

Education and society results

- Undergraduate and joint graduate courses within each research area, open for other universities. Summer schools for our graduate students.
- Popular articles in Swedish IT news media.

1.6 Summary of projects and resources

<table>
<thead>
<tr>
<th>Area</th>
<th>Project 1</th>
<th>Project 2</th>
<th>Project 3</th>
<th>Project 4</th>
<th>Project 5</th>
<th>Project 6</th>
<th>Project 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KTH</td>
<td>LTU</td>
<td>SICS</td>
<td>UU</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area 1</td>
<td>Project 1</td>
<td>0.5</td>
<td>2.5</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project 2</td>
<td>2</td>
<td>0.5</td>
<td>1</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area 2</td>
<td>Project 3</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project 4</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area 3</td>
<td>Project 5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project 6</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project 7</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5</td>
<td>5</td>
<td>4.5</td>
<td>6.5</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Summary of resources per project and partner (man-years).
Table 1 summarises the manpower allocated for each project and partner. There is an additional 7.4 unallocated man-years that is reserved for new projects within the programme, or as additional manpower to the above defined seven project. 2 man-years of the 7.4 are reserved for guest researchers.

The funds applied for from SSF will not cover the total cost of this programme. Some partners will provide additional resources in the form of work performed by faculty funded personnel. We also intend to seek additional funding from industry.

1.7 References


