ICT-MobileSummit 2009 Conference Proceedings
Paul Cunningham and Miriam Cunningham (Eds)
IIMC International Information Management Corporation, 2009
ISBN: 978-1-905824-12-0

Paths to Mobility Support in the Future Internet

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Abstract: The efficient support of various mobility types is one of the main challenges in anticipating evolutions towards the Future Internet. The European 4WARD project applies a "clean-slate" architectural approach where the Generic Path, a new communication abstraction, organizes the necessary cooperation between nodes for realising a wide range of communication services from unicast/multicast conversational services to multi point transfer between cooperating information objects. Our work addresses the challenges of supporting different mobility types in the context of Generic Paths by elaborating innovative schemes that will be further evaluated and combined in a second step. The Dynamic Mobility Anchoring proposal considers the distribution of mobility anchors in Access Nodes realising the necessary traffic indirection when hosts connectivities change. Anchorless mobility applies a more abstract approach where so called compartment are used to realise dynamic bindings between end points. A main issue for supporting wide scale mobility is the availability of a common namespace and an efficient resolution scheme. We address this issue with a high focus. Lastly considering mobile ad hoc networking as a key environment for its high level of dynamicity, we envisage the application of end to end concurrent multi-path transfer methods in such a context. Our research opens several future perspectives such as further designing, evaluating, refining and combining the different innovations and algorithms in a coherent mobility framework for Generic Paths.

Keywords: Future Internet, Mobility, Generic Path.

1. Introduction

In the framework of the European 4WARD project [1], new "clean" architectures are emerging to bring major networking innovations facilitating the support of future applications. Beyond typical mobility schemes supported in today's cellular networks, where device mobility is the key focus, Future Internet mobility will have to support movements of all kind of nodes but also of applications and information objects. This will be realised while several access technologies mostly wireless and optical based will become mature and largely deployed in areas that may overlap or not. Proper and coordinated resource handling of those various technologies require distinguishing between connectivity management and the mapping of traffic flows over the available (multi-technology based) access resources. For example, a multi-technology device may manage connectivity over two or more access technologies while having several ongoing traffic sessions at the same time. It is foreseen that mobility schemes will require different realizations at different levels in the network depending on movement types and considered moving entities (nodes, devices, applications…).

The "Generic Path" approach is currently proposed and designed in the 4WARD project for bringing a new "end to end" networking communication abstraction [2]. A "Generic Path" is set up between two (or more) communicating "end-points" enabling to organize the necessary cooperation between nodes. Mobility realization is one of the main concerns for Generic Paths, taking benefit of multi-connectivity and multiple routes between end-points. Beyond connectivity support, a proper distinction between addressing and naming components of each networking entity is recognized necessary. Indeed, while a given endpoint locator may change as a result of its movement between network attachments, this should not cause identity nor end-points modifications for the above entity using communication facilities.

While the Generic Path approach is a central innovation for future networks, complementary networking paradigms are explored within the 4WARD project and include others aspects related to mobility as introduced in [3]. In this article we concentrate on the description of our research aiming to provide an inherent and efficient support of mobility in the framework of Generic Paths. We are convinced that the adoption of future networks will highly belong to their support of various mobility types. This brings major concerns and we need to anticipate future problems that will rise when more and more hosts of highly different form factors and capabilities will be (inter) connected providing a so huge dissemination framework of information and communicating objects that it becomes absolutely unthinkable. To name a few, flexibility, scalability and security issues need to be anticipated when considering mobility.

In section 2 of this article, we provide a more precise description of Mobility Concerns in the context of Generic Paths. In section 3 we describe our technical approach through the different innovations currently developed. In the conclusion we mention interesting perspectives for our future work.

2. Mobility Concerns in the Context of Generic Paths

With the desire of today's user to access more and more Internet services and applications anytime, from any location and with any end device, uninterruptible service, robustness and reliability are becoming key issues in challenging mobile scenarios. As existing solutions are not designed for such environments they cannot provide an adequate user experience. Often the end-to-end principle "if you need to do complex things, e.g. keep state information, do it in the end system" was applied and lots of different own overlay networks were build [2]. Moreover the same functionality for error and flow control, routing and lookup of names to addresses, was provided over and over again on many layers. Therefore the 4WARD project [1] came up with a kind of largest common denominator, called a Generic Path (GP). This new transport paradigm generalizes the usual E2E path by organizing cooperation between nodes in a path, structuring cross-layer information, discover and control underlying topologies, performing multi-layer routing and the signaling between involved nodes.

A Generic Path can consist of more than one source and more than one sink and as such can possess more than 2 end points, thereby redefining the end-to-end principle. And the GP organizes delivery of chunks of information objects between multiple sources and multiple destinations (N:M) and consequently includes multi-cast as well as the possibility to exploit Network Coding. Summarized, the GP organizes access to information objects.

When entities become mobile, the choice of a suitable mobility anchor can become crucial. Then the Host Id may not be the ultimate hook for mobility to bind directly flows or applications to mobility anchors. Tightly coupled with the latter is the problem of name spaces and naming resolution. Mobility is mainly about maintaining connectivity and the main issue now becomes “what is the right connectivity level to maintain on each available interface” and “how to map ongoing traffic flows over these different systems”. Another crucial issue is to determine to what extend mobility is managed from inside and from outside of the GP.

Obviously, we anticipate many scenarios for mobility. For instance, a user might move during a wireless communication session such that the attachment point of the wireless channel of its device must be changed. In this case a typical handover might be performed without the user's knowledge. In multi-connectivity scenarios, the device may also be moved between overlaying access technologies due to network or applications needs (load sharing, changes in required or obtained QoS, resources availability…). A device may also simply move or duplicate its ongoing traffic flows over resources provided by its different connectivity interfaces. A user might also move the communication session itself from one device to another, for example watching sports on the TV and then transfer it to a mobile device when leaving home. Finally, the network itself may move while the user is stationary in the network, e.g. in a vehicle network. All these scenarios may lead to different networking support answers but we try to consider them more globally for providing a coherent mobility framework for Generic Paths.

To solve the above listed issues and concerns we need to further refine our GP model and to define additional concepts. An endpoint is the interface between the GP termination and an entity that makes use of a GP, e.g. an application. The network is a collection of nodes, with each node supporting one more endpoints. If a given endpoint moves from one node to another we talk of endpoint mobility. Thus GP mobility functionality is bound to endpoints. And as an endpoint is residing in a given node, the node itself has mobility properties and offers them to the endpoint. The endpoint mobility then allows to maintain a given GP even when the endpoint itself is transferred between two nodes. Thereby session mobility between different devices is provided, allowing for example a video stream to be transferred from a handheld device to a TV set.

With these concepts at hand we can we can start to tackle the technical solutions to the mobility problem in the next section.

3. Technical Approach

We currently have technical scenarios proposals that need to be developed in parallel, evaluated and compared in the objective to obtain a coherent mobility framework. Those different technical scenarios are further introduced in this section.

3.1 Dynamic Mobility Anchoring concepts

Mobility realisation generally relies on networks anchors responsible for traffic forwarding to the current location of the mobile node. The whole traffic of a mobile node is then routed towards its anchor in a centralised fashion. Such approaches can be optimised with hierarchical anchoring where, depending on the type of movement, a local anchor may mask the movement to the more global one's and the rest of the network. The well known Mobile IP protocol [4] applies such an approach where the Home Agent acts as mobile node's "global" mobility anchor whereas local anchors in given domains and access networks can be based on Hierarchical Mobile IP [5] for example. Cellular networks applies similar philosophy schemes with, for example, the use of SGSN and GGSN in 3G core networks [6]. These approaches being highly centralised and hierarchical, they may restrict flexibility and cause bottlenecks and single point of failure issues. More issues can be also observed such as traffic forwarding overhead.

The Dynamic Mobility Anchoring approach is based on the full distribution of mobility functions between Mobile Nodes and Access Nodes without requiring neither centralised nor hierarchical anchoring. Such a decentralised scheme ensures scalability in different contexts (from ad-hoc spontaneous to managed networks). It allows for a simpler network architecture and removes the single point of failure which a centralised mobility server otherwise could be. Mobility support is inherently offered by Mobility Anchors functions in Access Nodes implementing points of traffic indirections. Access Nodes are designed independently from the access technology they support, allowing deployment of different technologies in the same network (e.g. 802.11++, 3G+, 4G, or even optical). The network only supports GP construction and routing functions without mobility awareness whereas points of indirections are realised at its edges in Access Nodes. Instead of anchoring the whole traffic of a given mobile node, Mobility Anchors in access nodes are dynamically activated per GP and located at the "last hop location" (the Access Node) from the view of the mobile end-point at GP setup. Until the mobile node does not move, there is no need for any traffic indirection, thus the GP is re-routed to different Access Node only following mobile node's movements. When the given GP is end up, its anchor is deactivated whereas any new GP will be anchored at the current device's location. The indirection functions of a GP also deals with multi-interfaces capabilities by using multi-path routing facilities between the point of indirection and the end-point.

As a more concrete example, Figure 1 illustrates Dynamic Mobility Anchoring where a terminal has two valid simultaneous networks attachments, obtained through two different connectivity interfaces. These attachments form connectivity zone of the terminal, i.e. the set of Access Nodes on which it is reachable. Two communication GPs are set up: "flow 1" and "flow 2" anchored respectively outside and inside the connectivity zone. Those GP Mobility Anchors provide points of indirections for traffic delivery through the current connectivity zone. Different indirection policies can be applied, ranging from globally to the GP (e.g. the whole GP traffic is delivered via a given Access Node) to a per-packet based policy (each packet can be delivered via one of the current Access Nodes).

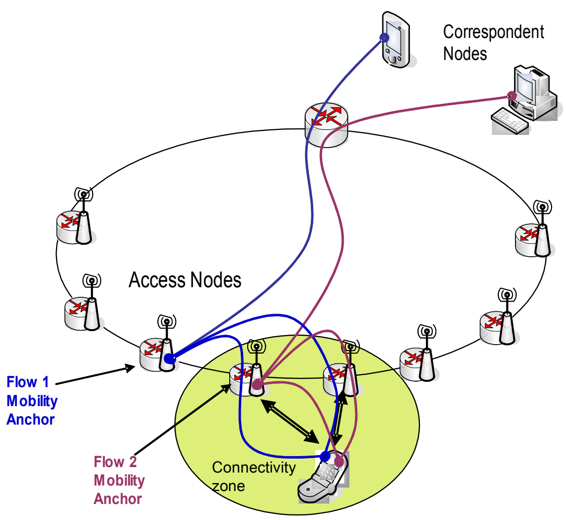

Figure 1: Dynamic Mobility Anchoring concept

3.2 Anchorless Mobility using Generic Paths and Dynamic Bindings

A more abstract component in the GP architecture is the Compartment (CT) defined as a cloud offering logical endpoints to information objects or applications. More accurately the

Compartment is a set of Generic Paths sharing common characteristics. The requirement of multiple connectivity functions in the terminals and the need to define new addressing schemes separating the address (locator) of the logical endpoint from the location where the endpoint is, gives rise to another abstract component of the GP architecture. We define a locator as an entity at the edge of a network defining a physical location in a network, e.g. a base station or a WLAN access point.

All these elementary components above share similarities in their functionality, which can be summarized in a generic function called binding. Following an object oriented approach for the decomposition we reason that logical endpoints, connectivity endpoints and locator endpoints share common core functionality. Thus a base class notion becomes applicable and naturally we call this common base class the EndPoint. EndPoints communicate to each other and to the outside world via a binding function and offer one or if necessary more than one link to participate in networking, see Figure 2. Depending on the networking strategy the EndPoints may operate stateful or stateless, dynamic or static, interpreting packets or manipulating packets traversing them.

EndPoints form the outer basic component of a Compartment and are visible from outside the Compartment. They are addressable from inside the Compartment and outside the Compartment they belong to, provide binding functions and offer the capability to hide the inner components of the Compartment. Thereby each Compartment can follow its own strategy to forward packets through its internal structures. The internal structural element attached to the EndPoint within a Compartment is the Generic Path (GP).

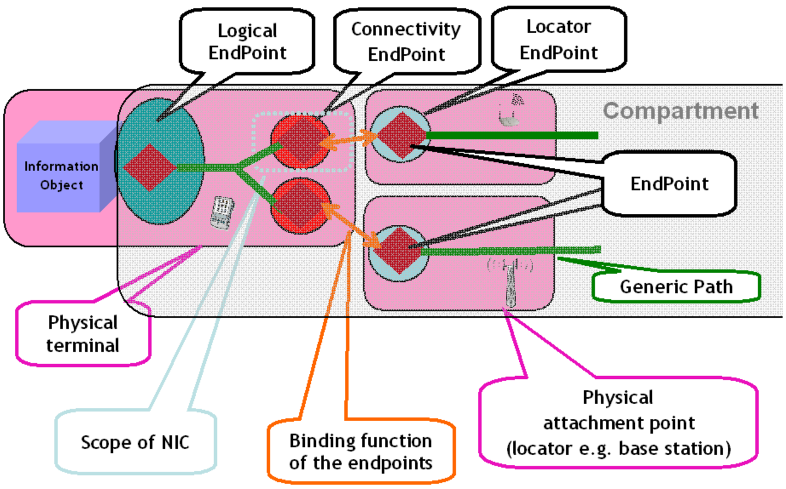

Figure 2: Generic Path and Compartment components

Given the introduced concepts above we are able to build real networks containing mobile components. Thereby the principle component that facilitates mobility is the dynamic binding function. In this model the EndPoints (EP) as such perform the mobility regardless if an EndPoint acts as Locator-EP, Connectivity-EP, Logical-EP or simply as border element of a compartment acting as a network or a domain. If for example the mobile terminal in Figure 2 is moving outside of the WLAN zone, the binding to that WLAN zone is torn down, while the binding to the base station is maintained.

3.3 Locators and naming

For the binding functions it is essential to understand what is being bound and to what. The different types of EndPoints have to be synchronized for proper network operation. For this, a clear way of referring to these EPs is a challenge that needs to be addressed by any mobility solution. Currently, different aspects of the network are addressed separately.

One of the advantages that the GP concept will bring is a simpler way of integrating all control of the path, including aspects like user oriented policies, attributes and data to link properties, network conditions, and path information. In a mobile environment, each of these control aspects typically operates in its own control space. So we can easily identify (access-)technology-mobility, network-mobility, transport mobility and application and service mobility. As there is no consistent approach to these mechanisms that enable mobility, the identifiers used in the process also suffer from the same problem. Each layer presents a different namespace (MAC, IP, and URI to name a few) and consequently a different identifier set with disjoint characteristics and no particular cross layer uniformity. There is no relationship between the identifiers used at different layers and each mobility procedure or protocol has its own meaning and conveys no useful information beyond the namespace where they originate.

We aim to solve this problem using identifiers as basic building blocks of the mobility mechanisms. This "Identity Driven Mobility" has four core aspects:

- The definition of a connection path between the communication end-points – the GP
- A common namespace that aggregates information;
- Path Mobility coupled with identities and identifiers, instead of normal numerical and string addresses;
- Meaningful identifiers that reference the identity namespace through dynamic binding (resolution).

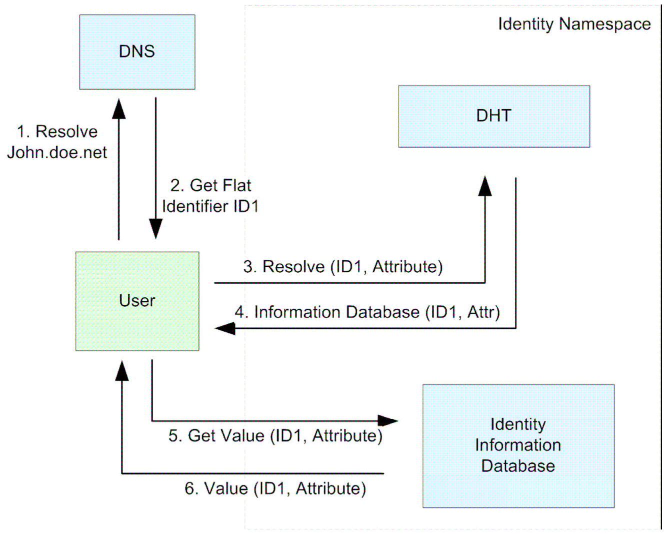

Figure 3: Example of a resolution with a resilient system in an identity-driven environment

The issues on the common namespace and its resolution are the central points here. It seems necessary that a common namespace must be used to unify information flowing from different layers and directing it into building communication paths that handle mobility, see [7]. We must have a clean namespace that is addressable by all layers and protocols. This namespace needs to contain information regarding the user and network context relevant to path establishment, which implies that both network and user information should be able to coexist in this namespace. Note that it is not required that a single entity keeps all the information because rather than an information holding, the purpose of a namespace is resolution, so that this information can be distributed across the network, eliminating single points of failure and performance problems. For instance, Figure 3 depicts a simple vision of how the resolution of a DNS name can be performed into the global identity namespace, in a distributed resilient environment. Even though this process seems long, its complexity and delay is feasible, and it provides a uniformity of operation to the GPs.

The choice for an identity namespace is due to several aspects: i) it is user centric; ii) it easily allows for distributed deployments of the resolution system, with shared ownership of the information stored in the namespace; iii) it is attribute-oriented (where attributes are generic bits of information that pertain to the user or any associated object). The existence of the identity space for mobility presents the opportunity of defining common grounds for the different mobility levels. A control layer, which is aware of multiple mobility events is now possible, since it will always relate to the same GP which can be linked to the identity namespace through the used identifiers, regardless of the technology instantiation being used.

3.4 Concurrent multi-path transfer

The Mobile Ad-hoc NETwork (MANET) is quite an interesting application for the Generic Path concept because it is a case where traditional distinctions between infrastructure and end points are blurred and cross-layer phenomena are exacerbated.

It is also a strong challenge to the design of an object-oriented model for the Generic Path. For such a model, the base class, inheritance tree and composition rules must provide as consistent and non redundant information as possible. Thus, for each feature being modelled, it is mandatory that generic and specific attributes are well delineated. Considering the dual roles of nodes (end points and routers), generic attributes should apply to both roles whereas specific ones should concern the specific differences between them.

Current MANET implementations on 802.11 networks face strong performance challenges with respect to node mobility. When a node moves it may disconnect from its current point of attachment and sooner or later reconnect, typically to another node. It induces not only a possible transfer interruption for itself but also for all the traffic that it routes. The routing table must be rapidly updated so that the routed traffic can be sustained. Furthermore, information objects that were being handled by or for the node must remain persistent within the network for long enough so as not to be lost but duly forwarded when the node reconnects, at least for delay-tolerant information.

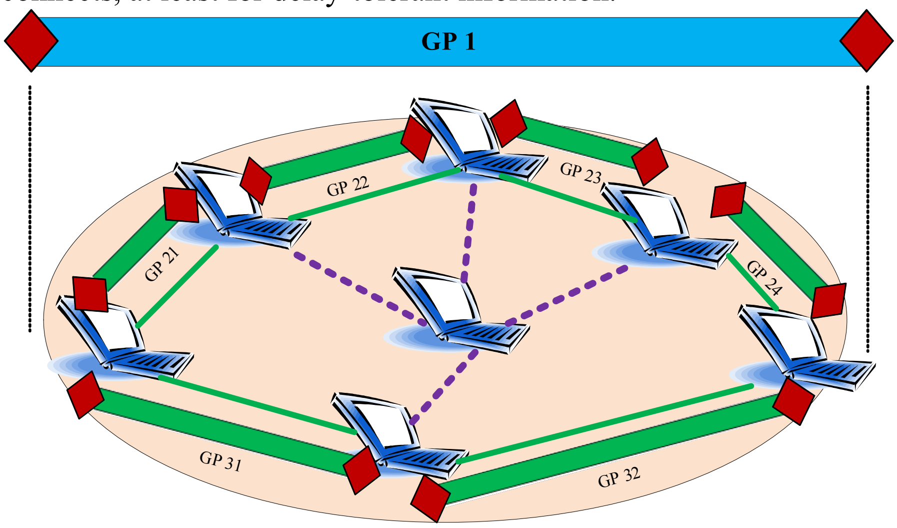

Figure 4: Generic Path view of Concurrent Multipath Transfer in MANET

A way to provide an order-of-magnitude performance improvement consists in using path diversity i.e. allowing the use of several simultaneous paths using the CMT (Concurrent Multipath Transfer) technique. Using two distinct paths along the whole route needs to solve local and end-to-end problems, such as optimal traffic balancing between paths and full route construction for example. A Generic Path composition model must allow the definition of a generic path as the combination of two distinct paths between which traffic is optimally distributed at the packet level using link-level and application-level information. Each individual path is itself a succession of hop-by-hop paths. This combination is highly dynamic as each node of the MANET can move. This is illustrated in Figure 4 where GP1 can be seen as an end to end transport GP using the combination of underlying GPs and routes.

4. Conclusions and Future Work

One important pillar of the Generic Path approach for the clean-slate design of the future Internet is a suitable mobility concept for complex communication scenarios and new upcoming services. We have introduced several mobility approaches ranging from dynamic mobility anchoring, anchorless mobility, naming and addressing schemes to multi-path transfer. All these approaches seem promising and fulfil major requirements concerning flexibility and scalability. Their combination will be essential for providing an efficient and flexible mobility framework for Generic Paths: the availability of a common namespace and an efficient resolution scheme is necessary for the realisation of dynamic bindings for anchored and anchorless mobility schemes; highly dynamic environment such as mobile ad-hoc networking reinforce the need for efficient and distributed mobility schemes whereas concurrent multipath transfer methods are taking benefit of multi-access facilities of Generic Paths.

Our current research is aiming to evaluate and compare those different approaches and their combination. The next steps will particularly comprise the definition of algorithms for the mobility framework described so far. These algorithms must then be analyzed and validated for their performance, stability and their reliability in the context of the Generic Path concept.

Acknowledgements

We would like to thank our colleagues in the 4WARD Work Package 5, aptly titled Generic Paths, for fruitful discussions.
This work has been carried out in the framework of the IST 7th Framework Programme Integrated Project 4WARD, which is partially funded by the Commission of the European Union. The views expressed in this paper are solely those of the authors and do not necessarily represent the views of their employers, the 4WARD project, or the Commission of the European Union.

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