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Integrating service discovery with routing and session management for ad-hoc networks ☆

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Abstract

In this paper, we propose GSR: a new routing and session management protocol for ad-hoc networks as an integral part of a service discovery infrastructure. Traditional approaches place routing at a layer below service discovery. While this distinction is appropriate for wired networked services, we argue that in ad-hoc networks this layering is not as meaningful and show that integrating routing with discovery infrastructure increases system efficiency. Central to our protocol is the idea of reusing the path created by the combination of a service discovery request and a service advertisement for data transmission. This precludes the need to use separate routing and discovery protocols. GSR also combines transport layer features and provides end-to-end session management that detects disconnections, link and node failures and enables service-centric session redirection to handle failures. This enables GSR to accommodate service-centric routing apart from the traditional node-centric routing. We compare GSR with AODV in terms of packet delivery ratio, response time and average number of hops traveled by service requests as well as data. GSR achieves better packet delivery ratio with a minor increase of the average packet delivery delay.

Keywords: Service discovery; Ad-hoc networks; Routing; Session management; Service-centric routing

1. Introduction

The growth of handheld devices ranging from cell phones to portable mp3 players to win CE iPAQs has opened up new research directions in the area of pervasive computing. These devices have varying resource capabilities. However, a large number of them have basic networking capabilities (GPRS, IR, Bluetooth, 802.11) to connect

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to peer devices. Current usage of these devices vary from localized access of capabilities (mostly) to accessing Internet-based Services (sometimes) to accessing rudimentary services from peer devices like downloading business cards (rarely). However, with the increase in the heterogeneity of information, capabilities and usage of these devices, the future holds an enormous potential for these devices to utilize services in peer devices using ad-hoc networking capabilities. Examples range from mobile commerce environments to battlefront environments to sensor networks. Mobile commerce examples include receiving discount coupons at malls, carrying out automatic checkout in grocery stores. Warfront activities and sensor networks often need to integrate data (that are offered by services on various devices/sensors) from heterogeneous sources to discover meaningful trends.

It can be argued that the fundamental reason for ad-hoc networks (also referred to as Mobile Ad-hoc Networks or MANETs) is for devices to use the services available from their peers in the vicinity. By ''Service'', we refer to any software component, data, or hardware resource on a device that it makes accessible to others. Service discovery and invocation are thus fundamental operations in an ad-hoc network. While there exists a huge body of work in service discovery in the context of wired-networks, research in the area of service discovery in ad-hoc networks is relatively new [1–3]. Solutions primarily utilize the broadcast-driven nature of the underlying ad-hoc network to carry out service discovery on various devices.

Service invocation is carried out after service discovery and involves sending of service invocation data to the desired service. Service invocation primarily utilizes underlying ad-hoc routing protocols [4–7] for its operation. Most prior work in the area of service discovery and invocation assumes that the process of service discovery and routing are only loosely coupled. To the contrary, it has been argued in [8,9] that cross layer integration of protocol stacks improve system efficiency. There has also been some work in utilizing service-centric data to route packets [10,11] for wired networks. AODV [4] defined a service extension to its routing protocol to incorporate discovery. However, as discussed in Section 2, the extension considers only bit-level addressing of services and is primarily based on the broadcast-driven nature of the AODV protocol. We argue that an efficient service discovery protocol can provide further efficiency to an integrated discovery and routing protocol. Furthermore, incorporating some transport layer end-to-end session management with the integrated layer provides greater reliability to end applications in an ad-hoc network.

Apart from the benefits pointed out in [8], integration of the service discovery with routing in ad-hoc networks provides the following benefits: (1) *Usage of available routes*: The discovery infrastructure while trying to discover a service discovers multiple possible paths to reach a service too. Typically, a discovery infrastructure discards this information. While this is not needed in wired networks (since network topology is fixed and there are very few route changes), it could be effectively used by ad-hoc routing protocols; (2) *Service-centric Route Enablement*: Multiple instances of the same service may potentially exist on different ad-hoc nodes. If needed, the integrated layer can use the information in the discovery infrastructure to route the invocation data to a *service instance* instead of a *node address*. This makes the integrated protocol *service-centric* instead of the traditional *node-centric* approach towards routing; (3) *Resilience to Service-Node Failures*: Moreover, all routing protocols are node-centric (they route based on the *node address* or IP address) and hence prone to failure of that node. Service-node failure leads to the service being unavailable leading to a service failure. Ideally, we would like service discovery and invocation to be immune to service-node failure since multiple instances of the same service could be existing on different nodes. We achieve this by combining the service discovery and routing layers. We borrow the notion of *path-repair* which is widely used in optical networks where the switching fabric is aware of multiple paths from source to destination. However, instead of multiple paths, the service discovery layer is aware of multiple instances of a specific type of service and the route to that service. In the event of a service-node failure, this new integrated layer can rediscover another instance of the service and deliver data to it. (4) *Reduced Routing*