Social Carrier Recommendation for Selecting Services in Electronic Telecommunication Markets

A Preliminary Report

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Abstract

The proliferation of telecommunication services and the need to manage quality of service on an end-to-end basis require an approach for automatically selecting services that provide sufficient quality of service at minimal cost. An agent-based approach is appropriate for such a purpose. For this reason, this paper presents a *social carrier recommendation* method, which is an essential component of application-level end-to-end quality of service management as well as a way to make the final step towards electronic telecommunication markets. For electronic telecommunication markets, the proposed approach provides a consumer-based evaluation of services as well as "rational" user agents that select services and carriers based on needs, offered prices, and ratings. Therefore, this approach complements existing market mechanisms that either provide means to buy services or intend to improve sales and customer service of carriers.

1 The Evolution of Distributed Information Networks

Distributed Information Networks (DINs) are developed to exploit the diversity of offered telecommunication services by utilizing multiple networks to minimize costs, circumventing technology limitations (e.g., lack of security and reliability) and insufficient *quality of service (QoS)*, as well as extending reachability and connectivity.

The need of an agent-based approach for automatically selecting services raises from the proliferation of services and the need to manage QoS on an end-to-end basis. These two reasons are discussed in Section 1.1 and Section 1.2, respectively. The agent system using a *social carrier recommendation (SCR)* method is explained in more detail in Section 2 of this paper. It minimizes costs and ensures sufficient QoS when choosing an appropriate service.

A user is assisted in SCR by a so-called User Agent that selects services according to the directives and observed preferences of the user. The presentation of SCR focuses on the selection process since agents acting as buyers in electronic markets exist already [KH96]. This leads in a natural way to electronic telecommunication markets in which telecommunication services are offered, traded, and bought electronically by agents. Such markets require also agents on the service provider side: Realizing services by means of mobile agents within end-terminals enables service subscription for single usages [Mag96], which is very attractive for an electronic telecommunication market. In [WBT95, Bus96], a customer is connected in the network of a provider to a customer agent that negotiates the service requests of the customers and pro-actively offers services to the customers. Before offering pro-actively services, a customer agent determines whether, for instance, the current price is attractive for a customer. Especially, this will become important if pricing is dynamic and based on current load, as it is the case in [WBT95, Bus96]. Such customer agents improve the service offered to the customer by a single service provider. A true electronic market requires the herein proposed user agent which would evaluate pro-active offers (e.g., to find a time when a service is cheap) and interact with the corresponding customer agents of all carriers in the market. In addition to this, the community of user agents would rate the delivered services and recommend services based on this rating. Hence, this community represents an electronic consumer organization.

1.1 Proliferation of Services

In the information age, telecommunication is used for communication between people, to distribute information and electronic services, and to coordinate processes. These applications pose very different requirements on telecommunication services. For instance, researchers employ the Internet to locate and disseminate information, whereas residential users might be mostly interested in communication between people [KSM+96]. The most successful telecommunication services are the ones that meet best the requirements of their target market, which results in a proliferation of services. Even the introduction of universal protocols (e.g., ATM and IPv6) and the standardization of network application interfaces (e.g., *Integrated Service Digital Network (ISDN)* and TCP/UDP) do not prevent the proliferation of services because of:

- the competition in liberalized and global telecommunication markets requires market differentiation as well as focusing on particular markets;
- different service classes (e.g., best-effort, real-time, and so on) requires usage-based pricing, as the Internet community is finding out; and
- multiple networks with different capabilities exist due to the evolution of networking technologies and, more importantly, the variety of available transmission media (e.g., wire-line and wireless).

This trend is not reversed by the Internet since it consists of multiple networks which cover partly the same geographical area. Since the start of the privatisation of the Internet, individual networks of the Internet are administrated by distinct service providers. Therefore, it becomes much harder within a multiple administrative domain to meet the specific QoS requirements of service classes. In particular, the development of performance management protocols and tools become difficult.

Considering the proliferation of the services from the user's view, some other problems have also to be solved. The customers have to choose appropriate services and service packages for their applications in such a free market. This is difficult for the average consumer and also not its primary task. For instance, the long-distance *Public Switched Telephone Network (PSTN)* service providers in the U.S. make frequently time-limited special offers to increase their market share. But, some customers are becoming tired of these special offers. Furthermore, a free market functions only if there is sufficient consumer feedback. A special offer might lure a large number of customers, but results in a degradation of the QoS. For instance, the availability of the local call PSTN is reduced in some areas of the U.S. due to the long connection time of Internet users.

1.2 End-to-End QoS Management

Today's QoS management is insufficient and inappropriate for DINs because:

- QoS is an end-to-end property experienced by the application and no service provider has global control about all networks. In particular, this limited control is visible in Global Area Networks, for which Albanese et al. propose *application-level network management* [ABE+96]. Clark propagates application-level management for high-speed protocols, because the application knows best how to handle packet loss, delay, and so on [CT90]. Last but not least, globally coordinated QoS management is potentially very expensive. Therefore, an agent-based approach managing the QoS on application level might reduce theses expenses.
- The decentralized network model (e.g., embodied by the Internet) with its often powerful end-terminals (i.e., computers) is well suited for application-level network management. Such end-terminals empower

applications to judge the QoS themselves and to choose carriers. Note, that a nearby management server could control a whole range of end-terminals (e.g., mobile devices and network computers) which have only a limited computing power.

- A hierarchical QoS management approach (aggregated QoS information is employed at the higher level) would not be very useful for global networks. Such an abstraction implies a loss of precision and is difficult to determine.
- In a competitive environment, it is unlikely that the service providers exchange extensive QoS data which enables one to evaluate networks of competitors. Such an exchange of information about the network status (e.g. load, delays, congestion, and so on) is required for QoS routing, for example.
- The perceived QoS depends on the user of an application, the situation, as well as the application itself. Therefore, it is necessary to enable the user to specify his needs in particular situations. These requirements have to be mapped into network service QoS requirements [AS96].

Since the routes of information flows have to be determined, the selection of a service provider is of particular interest in this paper. For this purpose, *source routing* is required to enforce the choice. IPv6 [DEF+95], for instance, provides the necessary support, which is also required for QoS routing. Source routing for provider selection is different from *policy routing* [Cla89], which enables network providers to route traffic based on policies. Nevertheless, many issues are the same for both approaches. The implementation of source routing for service provider selection is not further discussed in this paper.

2 Social Carrier Recommendation

The basic idea of SCR is to adapt *social information filtering* techniques [SM95] for recommending services, i.e., enable users with similar applications and with similar communication needs to recommend services and service providers, respectively. The SCR provides assistance to a *user* for selecting appropriate services and carriers (or service providers) for the applications the user utilizes.[1] This Section focuses on the selection process, because agents acting as buyers on behalf of users exist already [KH96].

2.1 The SCR User Agent and its QoS Manager Function

A *SCR User Agent* keeps track of

- the user's expectations (i.e., user-level QoS), which are recorded in a *User Profile*,
- the applications used and their requirements, (*Application Profile*) and
- service agreements and the measured delivered QoS.

A SCR User Agent (see Fig.1) has to handle multiple devices, some of which use the same communication services. Therefore, a user agent is itself a distributed and mobile agent system in general. This does not impact the task of a user agent, so that this paper assumes without loss of generality for explanatory purposes that a user operates only a single device.

The User Profile defines what applications a user how uses, i.e., the time of the day, the frequency, and the user's expected QoS. An Application Profile defines the generic application specific requirements. For instance, best-effort services might specify a minimal required bandwidth and maximal consumable bandwidth. A user profile might specify a higher minimal required bandwidth for a file transfer service in order to take into consideration the wish of the particular user to complete file transfers in a short time. These expectations depend on the time of day: a user might demand shorter file transfer times at the end of his working

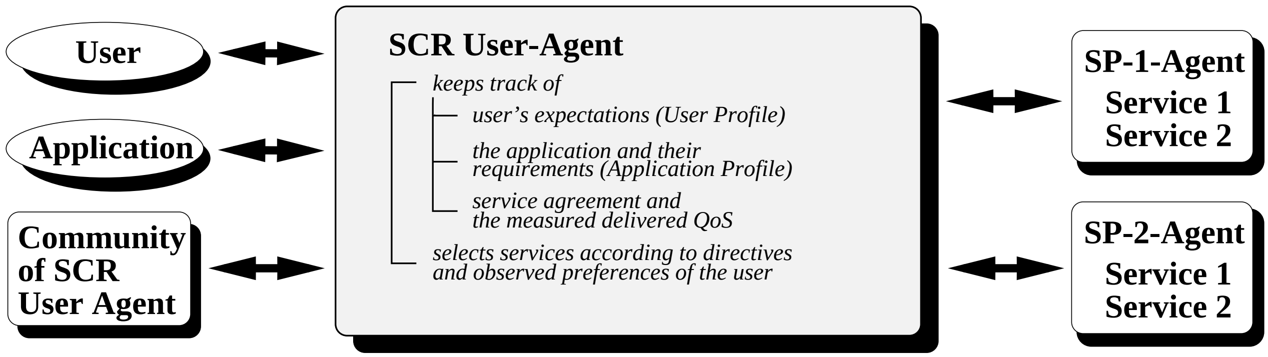

Figure 1: Structure of the SCR System

days. User profiles are constructed from observing the user and the user's requirements communicated to the application (see, for instance, [AS96]).

The SCR User Agent is an application-level QoS manager, because the user agent carries out the following steps for each communication:

1. Selects a service and a service provider to build up a connection and to route packets based on the required QoS and on the ratings of services and service providers.
2. Measures the QoS of the received service.
3. Compares the measurement result against the service agreement.
4. Rates the received service based on the comparison and its previous experience, and shares its experience with the community of user agents. The methods for service and provider rating are explained in greater detail in Section 2.2.1 and Section 2.2.2, respectively.

The service might be on-demand and subscription based. That means the SCR User Agent has to take into account the minimal duration of a subscription. For instance, PSTN requires a subscription for the access and is on-demand for the calls. However, there are mobile telephony services without subscription, because each call is payed using electronic cash (stored on a smart card). More single usage subscription services might be offered in the future based on mobile agents [Mag96]. In addition, multiple services might also be bundled to service packages, which are offered on a subscription base. For instance, Internet Service Providers often offer not only Internet access but also an e-mail account, web-page hosting, and so on.

It is important to understand that the SCR user agent specifies only carriers with which the agent deals directly. In particular, the providers of these carriers are not taken into consideration by the user agent even if it is possible to determine such providers. In the case of PSTN in the U.S., a user agent would specify a first local provider, a long-distance provider, and a second local provider. The user agent does not take into account whether a long-distance provider is a reseller or possesses its own network.

2.2 Rating of Flows and Carriers

The particular use of a service over a route of carrier networks is called a *flow*, i.e., a transport of one or more packets along a particular route. The flows are further classified according to their time of the day as well as the expected QoS (including availability). All flows are initiated and terminated in a *local network (LN)*. For instance, LANs, ISPs, and local PSTNs are local networks. SCR user agents obtain flows automatically by monitoring and classifying the usage of the services by applications (and, hence, users). Flow classes consist

[1]In general a distinction is made between the customer that pays for a service and the user that consumes a service. For explanatory purposes, we assume that the user is also the customer.

of flows which use the same service at the same time with the same QoS but differ in the User Profile and the Application Profile.

To recommend the best route for a service, the SCR User Agent uses *ratings* of past flows classified into the same or *similar* classes. For this purpose the past flows of a whole community of users were acquired. A rating is a number that describes how well a flow met the expected (and required) QoS. For instance, a possible rating scale is "missed required QoS", "met required QoS but missed expected QoS", and "met required and expected QoS". Flow classes are similar if they require the same service but require a slightly different QoS.[2]

The method for recommending carriers (as described in Section 2.2.2) is required, because the SCR User Agent falls back on the carrier rating for determining a QoS carrier routing, if no appropriate experience for a certain flow class is available.

2.2.1 A Method for Flow Rating

A flow is initiated and terminated in a local network, so that the message intensive aspect of the recommendation process is inherently local. Hence, the recommendation process should scale. This means that a community of user agents exists for each local network. Note that the locality is defined by the address of the local network which might not correspond to the geographical extension of the local network provider but is relevant for routing.[3]

The *Social Flow Rater*, a subagent of the SCR User Agent, carries out the following tasks:

1. The delivered QoS is determined to rate each single flow. The rating of a single flow is aggregated to a *user flow rating (UFR)* which is based on the previous N assessments. As pointed out in [SM95], the parameter N determines how much a user values past experience. In other words, a large N characterizes loyal customers.

   Note that techniques for measuring delivered QoS exist [AS96] and, hence, they are not further discussed in this paper. To increase the confidence in these measurements, certified measurement procedures could be made available for each service by an independent body. Carriers could give their consent for such a procedure by including it in the service agreement.

2. If the value of a UFR changes, the SCR user agent informs the other user agents of the community associated with the local network. Each SCR user agent computes the *community flow rating (CFR)*.

   Note that a low value for N, increases the probability that the UFR changes, which implies an increased overhead. Hence, this parameter enables to trade computational complexity against accuracy.

3. The available flows for serving an application between two end-points are ranked according their CFR. The highest ranked flow class is recommended to the application.

   If there is insufficient experiences with a flow class of a service or similar flow classes, finally, the experiences with the carrier are employed (see Section 2.2.2).

The Social Flow Rater can be implemented either in a client-server fashion with one server per community (associated with a local network) or fully distributed. There are trade-offs with respect to reliability, accuracy, communication costs, and computational complexity. However, the kind of implementation should not be of interest here.

2.2.2 A Method for Carrier Rating

The method of recommending carriers is applied if there is no sufficient experience (e.g., a service should be used the first time) with a certain flow class specified by the service the community wants to use (as

[2] From the definition of a flow class, it is possible to adjust the ratings for similar flows.

[3] In the case of Low-Earth-Orbit (LEO) satellite networks, the routing is determined by the geographical position of the service consumer. For the recommendation, the atmospheric conditions that influence the quality are taken into account. The time of the day would take care of the satellite availability.

mentioned in Section 2.2.1). The result of this method will be a rating of different possible flows fulfilling the requirements of the service.

In order to obtain possible flows which meet the requirements of the service, two steps have to be executed by the *Social Carrier Rater*:

1. Appropriate routes have to be found between the local network carrier (LN_i) of the local community and the local network carrier (LN_j) of the called person. For this purpose a database of existing LDs is accessed.

2. The routes found in the previous step have to be evaluated by using the information of the flows, respectively flow classes. Each flow of the certain flow class is divided up in the carriers involved. For each of these carriers a rating is generated by the procedure described below. If no information about the carrier is available in the certain class, similar flow classes are considered and evaluated. If even there is no information (i.e. experience) about these classes available at all, the user agent could work with aggregated QoS information provided by the network or simply use a generate-and-test approach to gain experience.

The remainder of this section describes the generation of the carrier rating precisely. The local network carrier rating is obtained by combining the ratings of all flows between locations within the local network. This combined rating is called *community carrier rating (CCR)*. CCR takes the similarities of the users (i.e., their profiles) into account by employing social information filtering techniques [SM95].

Long-distance carrier rating (LDCR) is more difficult, because no traffic is originating or terminating within a *long-distance network (LDs)*. The schema proposed here is applicable to flow routes over multiple long-distance networks. That means that this paper considers flows of the form LN-(LD)^i-LN.

Different QoS parameters have to be accumulated differently [WC96]. Consequently, a QoS rating approach has to operate on a vector and to apply the appropriate operations. For instance, the rating of a flow is the sum of the rating of the local carrier networks and the rating of the long-distance network.

$$R(F_i) = R(LN_l) + R(LD_k) + R(LN_j),$$

whereas F_i, $R()$, LN_i and LN_j, and LD_k denote the i^{th} flow, the rating function, the two local carrier networks, and the long-distance carrier network, respectively.

$$R(LD_k) = R(F_i) - R(LN_i) - R(LN_j) \tag{1}$$

Equation Eq. 1 enables the SCR user agent to determine $R(LD_k)$ given the ratings of the two access networks. This equation is only valid for routes over a single long-distance network, but it is simple to derive the equations for longer routes with methods of linear programming. For instance, n routes over more than one long-distance carriers are found in the particular flow class to which the required service belongs to (the LNs are already extracted from the equations)

$$\begin{aligned}
R(F_1) &= B_{1,1}R(LD_1) + B_{1,2}R(LD_2) + \cdots + B_{1,m}R(LD_m) \\
R(F_2) &= B_{2,1}R(LD_1) + B_{2,2}R(LD_2) + \cdots + B_{2,m}R(LD_m) \\
&\cdots \\
R(F_{n-1}) &= B_{n-1,1}R(LD_1) + B_{n-1,2}R(LD_2) + \cdots + B_{n-1,m}R(LD_m) \\
R(F_n) &= B_{n,1}R(LD_1) + B_{n,2}R(LD_2) + \cdots + B_{n,m}R(LD_m)
\end{aligned} \tag{2}$$

whereas m is the number of all LDs. $B_{i,j}$ indicates whether a flow F_i is routed via LD_j by having a value of 1. Otherwise, it is set to 0. Furthermore, the possible route r (see *step 1*) which can be used by the required service is evaluated by the so called *objective function* where $P_{r,i}$ denotes the usage of route r in the same way as $B_{i,j}$. The objective function which has to be minimized is

$$\text{Minimize} \quad Z = P_{r,1}R(LD_1) + P_{r,2}R(LD_2) + \cdots + P_{r,m}R(LD_m) \tag{3}$$

which is subject to the primary constraints

$$R(LD_i) \geq 0, \quad \text{for} \quad 1 \leq i \leq m \tag{4}$$

The *normal restricted form* required for solving the equations with the simplex method [PFTV88] can be generated from the equations Eq. 2 and Eq. 3. On applying the simplex method the ratings of the LDs are obtained which minimize equation Eq. 3.

If all ratings of the long-distance carriers are already known, one could use the equation Eq. 3 to validate (and probably improve) the ratings and uncover discrimination between long-distance carriers.

If a local carrier knows that the rating is calculated with equation Eq. 1, then it could discriminate against a particular long-distance carrier by providing poorer service to traffic to and from this long-distance carrier network. To prevent this, it is necessary to combine the ratings obtained by all the communities associated with the local carriers. Hence, one obtains a joint rating for a long-distance carrier, whereas its quality is defined by the deviation of the values. An arbiter could ensure that the deviations are kept below a certain threshold. This market policing is insufficient if a majority of local carriers discriminate against a particular long-distance carrier. This is the only possibility of cheating, if an implementation of social carrier rating support proper authentication and security. In such a situation, it would be necessary to measure the service provider's performance independently.

The foremost method computes ratings for single flows. For rating packages (consisting of different services) and rating the best basic transport service for a user (with a certain mix of applications), it is also possible to apply social filtering techniques.

3 Conclusions

The proposed social carrier recommendation approach (SCR) is an essential component of an electronic telecommunication market as well as of an end-to-end quality of service management. For performance management, SCR provides the application-level quality of service routing decisions. For electronic markets, SCR provides a consumer-based evaluation of services as well as "rational" user agents that select services and carriers based on needs, offered prices, and ratings. Therefore, SCR complements existing market mechanisms that either provide means to buy services or intend to improve sales and customer service of carriers.

Furthermore, service providers could also benefit from SCR by taking the rating (i.e., a customer feedback) into account for adapting their service offers. For measuring the performance of web-sites, Net.Genesis and net.Sweep offer performance analysis by monitoring web-sites from distributed polling stations [CW996]. Besides, the SCR can be used as a tool to check whether a network is over-booked. Over-booking is a technique to increase the network utilization. Customer agents which negotiate with the customer in the carriers system facilitate to determine appropriate levels of over-booking. SCR prevents excessive over-booking.

Privacy and security is a major concern in an implementation of a user agent because user agents possess data about users' preferences, loyalty, ratings, and so on. SCR provides a social rating service for which all beneficiaries share their experiences. Further research, i.e., an implementation or simulation, is necessary to determine the size of communities, the traffic generated, and the granularity of flow classification. In addition, it is necessary to study the handling of multiple network access points between carrier networks as the routing is no longer characterized by a simple sequence of service providers.

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