HyLearn: A Mobile Learning System for Hybrid Networks

Matthias R. Brust, Adrian Andronache, and Steffen Rothkugel
Faculty of Science, Technology and Communication (FSTC)
University of Luxembourg
Luxembourg
{matthias.brust, adrian.andronache, steffen.rothkugel}@uni.lu

Abstract

In this paper, we introduce HyLearn, a cooperative learning system for mobile devices running on a hybrid wireless network. HyLearn deploys information to interested nodes through both fixed as well as mobile networks. Due to the mobility of nodes, an efficient approach for self-organization the ad hoc network is required. For that, we apply a multi-hop clustering technique that forms hierarchical structures of an otherwise flat network in order to match HyLearn's expected communication pattern. This clustering algorithm is parameterized in terms of cluster size and can therefore adapt the size according to the mobility degree of nodes. Local information only is required to establish and maintain clusters.

1. Introduction

Nowadays, cell phones, notebooks, MP3-players, digital cameras, UMPC (ultra mobile pc) and other handheld communication devices are not to exclude any more from our daily life. An increasing number of mobile devices are able provide both a costly link to the Internet via a backbone network as well as ad hoc communication with neighboring devices that is free of charge [1]. A hybrid wireless network can make use of UMTS/GSM/HSDPA links to an infrastructured network and Bluetooth or Wi-Fi links in order to communicate in ad hoc fashion. The objective of hybrid network infrastructures is to combine the advantages of both network types whereby the ad hoc communication aspect is a task highly difficult to tackle. Often clustering is used in order to form hierarchical organizational structures of an otherwise flat network [2].

The target application HyLearn introduced subsequently is a distributed m-learning platform supporting cooperative learning for hybrid wireless network. Podcasts are used to provide learning material. HyLearn employs clustering in order to optimize the discovery and dissemination of such podcasts. Hereby, the cluster size is a critical parameter that must be carefully controlled in order to efficiently manage the message overheads in the ad hoc networks.

For this purpose, a k-hop clustering algorithm, called KHOPCA has been applied. KHOPCA is introduced and described in detail in [3]. The algorithm works asynchronously with local 1-hop neighborhood information only and is fully distributed and the cluster size can be controlled by the parameter k. Intra-cluster and inter-cluster communication are not described in this work, rather the focus is mainly on the hybrid network communication mechanism.

The remainder of this paper is organized as follows. Section 2 describes the HyLearn application scenario. Section 3 introduces the KHOPCA clustering algorithm. Research related to m-learning in hybrid wireless networks is given in Section 4. Future work and conclusions in Section 5 finish this paper.

2. Mobile learning via podcasts

One drawback of providing information only from within a local ad hoc network partition is that information cannot be exchanged easily across different types of networks, e.g. between groups of devices that use Bluetooth and other that use Wi-Fi. Another drawback is that devices are limited to search for information of interest solely in the current network partition.

There is an increasing number of mobile devices equipped with different network adapters, i.e. Wi-Fi, Bluetooth and cellular connections. Such devices are used in our system model to establish so-called *hybrid networks*. Hybrid networks overcome the limitations inherent to pure ad hoc networks by establishing local groups of communicating devices in a self-organizing manner and introducing dedicated uplinks to a backbone infrastructure. Such uplinks are used for

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accessing resources available in the Internet. Additionally, they are employed to directly interconnect distant devices, either within a single partition and particularly also across different partitions as well as different network types.

The HyLearn application applies the well-known podcast mechanism to disseminate learning material [4]. A podcast is a multimedia file distributed over the Internet using the syndication feeds mechanism. The provider—called podcaster—creates the content to offer and posts the information on a Web server. The location of the post is expected to be permanent. The episode is posted as element of a syndication feed in RSS format, which provides information about the series and its episodes such as publishing date, title, description and so on.

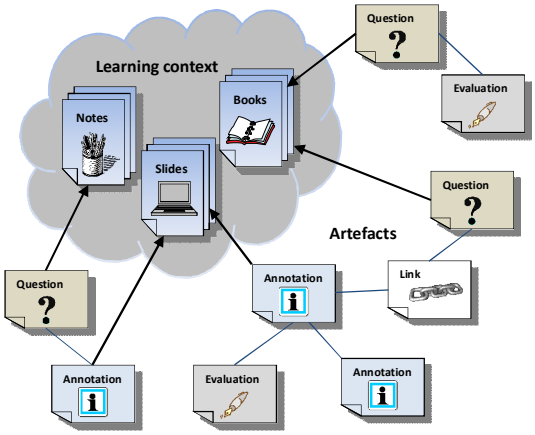

Figure 1. Learning material is distributed to students that attach artefacts. Artefacts can be evaluated by participants.

2.1. HyLearn

HyLearn is a distributed learning application explicitly designed for mobile devices connected via a hybrid network. HyLearn allows students to have personalized sets of their teaching material including annotations, questions, and links (cf. Fig 1).

By using the HyLearn application, students can augment the received teaching material by adding student-created artefacts [5], thus creating own episodes of the podcast. While recapitulating the material later on, students can use questions to get a deeper understanding of the topics covered. Students are encouraged to add annotations to the teaching material, slides, and questions. Moreover, students might discover additional relationships between some sections of the teaching material, their annotations, and the questions, adding them to their material (namely links). During runtime, the subset of available material can be augmented by meeting other students. Students are able to evaluate artefacts in respect to their usefulness to prevent misleading or false supplements to the teaching material from being distributed. Students can use the system for example during and after lectures, being able to join cliques by sharing their material, and can help each other in a cooperative and collaborative way, e.g. to prepare exams.

HyLearn is expected to work much more efficiently in hybrid wireless networks with the additional backbone links, as opposed to pure ad hoc networks only. However, a permanent backbone link is typically expensive. In our hybrid network model, the backbone link is just used on-demand in situations where it is helpful. Imagine for instance a large PowerPoint-presentation with many slides. For each single student, retrieving these slides over the backbone link individually would induce a high communication load. However, joining a group of wirelessly connected devices enables the devices to get data of interest from the ad hoc network. In such settings, only designated device obtain the slides from the backbone and provide them to the group members, which reduces the load on the backbone links.

The teaching context is a common set of lecture-related information, initially distributed by the lecturer in form of podcasts. The HyLearn application running on the student's devices will discover the new podcast in the ad hoc network thus enabling the students to subscribe to it. By subscribing to the lecture podcast, the students will be provided with the lecture material from teachers' notebook instantly without the need to use an Internet connection.

Managing the teaching material together with the data added by the students is a challenging task. We assume that students at different universities have different lectures and learning material related to the same domain.

To enable HyLearn to search and provide podcasts of interest in other network partitions or in different mobile networks the *HyTrace* mechanism is introduced. It enables students to search for podcasts related to their current interest in foreign networks, like ad hoc networks on the campus of other universities. To achieve this, HyTrace organizes the ad hoc network in clusters by electing local leaders called clusterheads, which will maintain uplinks to a backbone server. For this, only devices with a backbone connection will be elected as clusterheads.

The HyLearn users can search for learning podcasts by entering keywords related to the lecture of interest. HyTrace will send the search query to the local clusterhead, which will forward it to the backbone.

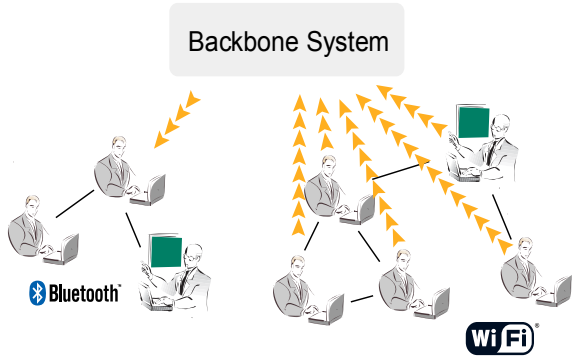

Figure 2. The search query is injected to each node; backbone receives redundant results.

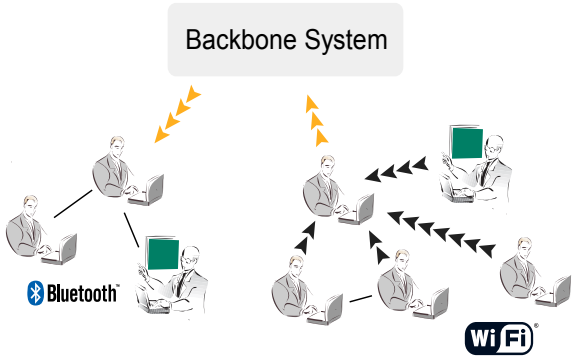

Figure 3. The backbone is unloaded if the query is injected only to elected devices.

The HyTrace backbone will inject the search query to all registered clusterheads, thus requesting devices in different networks and network partitions. When a clusterhead receives a search query, it sends it to the neighbor ad hoc devices, thus performing a local search. The podcasts feeds on the network devices that match the keywords of the query will be sent to the backbone via the local clusterhead. The backbone forwards the matching feeds to the requesting device and caches the podcast to satisfy further search queries directly (cf. Fig. 2 and Fig. 3).

HyTrace uses a cluster topology in the ad hoc networks in order to minimize the number of uplink devices in a partition. This reduces the number of search queries sent to a network partition as well as the number of redundant results sent to the backbone from a network partition (see Fig. 3).

One of our main goals is to optimize the number of backbone uplinks in a local network partition, thus reducing redundant communication between the backbone and the partition. To achieve the required network architecture, we propose to apply the k-hop clustering algorithm KHOPCA, which reduces the number of clusterheads by forming multi-hop clusters [3].

3. Group management with KHOPCA

A cluster is a group of interconnected nodes with a dedicated node called clusterhead. Clusterheads are responsible for cluster management, such as dissemination of control messages and data aggregation. Therefore, the role of the clusterhead is crucial for the proper network operation.

Our approach fosters on clustering for the ad hoc topology management in the HyLearn learning network.

However, in contrast to existing clustering algorithms, the clustering applied should create k-hop clusters, i.e. clusters with a diameter of at most $2k-1$ hops with the clusterhead centered.

A clustering algorithm with such a characteristic can be dynamically adapted in the size of the learning groups as well as on the load of the backbone network.

In the start configuration of KHOPCA, a participating node knows the clusterhead weight, i.e. the weight when a node is assumed to be a clusterhead, and the minimum weight. These weights are named MIN and MAX. Then, the difference between MIN and MAX correspondents to k.

Because of its weight, a node is aware of its hop-distance to the closest clusterhead.

Each node is continuously involved in the process of k-hop cluster formation and cluster maintenance. KHOPCA does not require any predetermined initial configuration. A node can potentially choose any role, i.e. weight w_I, in the beginning as well as at any time.

The value of k (difference between MIN and MAX) determines the maximum number of levels, or hops. Obviously, k should be chosen carefully depending on the mobility degree as well as influenced by application requirements.

For instance, the HyTrace search mechanism requires a minimal number of clusterheads in the network partition in order to minimize the redundant data exchange with the backbone. On the other side, there are applications like news providing services, which require that the data send from backbone reaches fast the ad hoc network nodes. To achieve this, an increased number of clusterheads that can disseminate the information to the cluster members by a few hops is need. The value of k can be determined, and even changed dynamically, simply by informing the clusterheads. Clusterheads in turn will propagate this information periodically to other nodes as part of a beacon.

4. Related work

This section gives an overview on mobile learning applications in hybrid wireless networks. In fact, it appears difficult to compare m-learning scenarios that are based on hybrid network infrastructures, because the hybrid concept can be understood and realized in many ways. Following applications, however, fit in our concept of hybrid networks.

DistScript [6] is a collaborative m-learning tool with the objective that all the students cooperate to take notes on a lecture in order to write a single script, common to all students. At the beginning of each lesson the lecturer distributes the corresponding slides to those students that have subscribed to the lecture during the first lesson. Each student has the possibility to request, during the lesson, a "write token" from the lecturer's laptop. This token-system is used to insure consistency. When receiving a token, the student is granted the right to add or edit notes, to ask or to answer questions.

The P2P project [7] wants to establish support for learning communities via mobile systems based on peer-to-peer networks. Learning communities are defined "as a group of members which use network-interconnected computers to develop their individual knowledge, about a specific subject, using their personal resources, and in collaboration with the rest of the community members."

"Learning from Starlight" [8] is a project to "implement a new approach to classroom astrophysics integrating mobile technologies to show the real essence of Astrophysics to students". No new application was implemented for this workshop; the importance of the project lies in showing how one can deploy a hybrid wireless network in order to favor collaboration among students for a given subject. The project will therefore not be analyzed under the aforementioned aspects of data distribution and collaboration.

5. Conclusions and future work

HyLearn, a distributed cooperative m-learning application for hybrid wireless networks is introduced in this paper. We propose to use the podcast mechanism for the dissemination of teaching material. In order to minimize the backbone uplinks clustering as method is proposed.

In particular, KHOPCA, a k-hop clustering algorithm is assigned to manage the ad hoc network environment of HyLearn. KHOPCA is shown to be highly adaptive to mobility and works with local 1-hop neighborhood information only, asynchronous, and fully distributed.

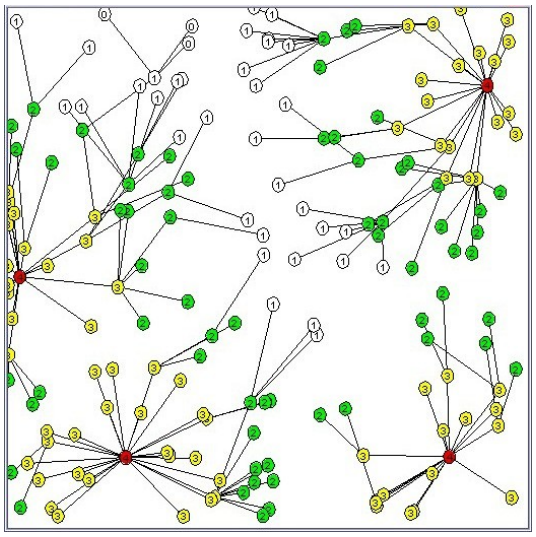

Figure 4. KHOPCA with $k = 4$

In the presented hybrid network model, the backbone uplinks can be used for inter-cluster communication. For intra-cluster communication, however, the communication protocol still has to be specified.

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