FH JOANNEUM
University of Applied Sciences

Direct Peer to Peer Communication on iOS Devices

When mediator based technology is not available

Bachelor's Thesis

submitted in conformity with the requirements for the degree of

Bachelor of Science in Engineering (BSc)

Bachelor's degree programme **Software Design and Cloud Computing**

FH JOANNEUM (University of Applied Sciences), Kapfenberg

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Abstract

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Keywords: FHJ, SWD, iOS, peer-to-peer, ad-hoc, smartphone, Apple

Kurzfassung

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1 | Introduction

> *Most smartphone communication leverages one hop radio links to cell towers or WiFi access points. In recent years, however, the major smartphone operating systems have included increasingly stable and useful support for local peer-to-peer communication that allows a device to talk directly to a nearby device (using local radio broadcast) while avoiding cellular and WiFi infrastructure. The ability to create these local links, combined with the ubiquity of smartphones, enables scenarios in which large groups of nearby smartphone users run applications that create peer-to-peer meshes supporting infrastructure-free networking. There are many possible motivations for these smartphone peer-to-peer networks. For example, they can support communication in settings where network infrastructure is censored (e.g., government protests), overwhelmed (e.g., a large festival or march), or unavailable (e.g., after a disaster or at a remote event). In addition, in developing countries, cellular data minutes are often bought in blocks and carefully conserved—increasing interest in networking operations that do not require cellular infrastructure.*
>
> *(Newport, 2017)*

This thesis analyses and measures the capabilities of the latest iOS devices to communicate via direct Peer to Peer (P2P) networks. Since most of current technology standards rely heavily on external infrastructure with powerful receiver antennas, direct P2P communication is not yet wide spread or optimized to function over long distances. However it is unclear, where the boundaries of the current implementations lie and therefore which type of applications could be implemented with direct P2P. The results aim to help assess feasibility of different implementations.

1.1 Motivation

Motivation. Modern mobile devices can make use of a wide variety of communication technologies. Besides having different applicabilities and protocols, standards like Bluetooth, WiFi or 5G need to be wireless to seamlessly transfer data. In resent years global economic demand has impacted research and development to vastly improve data transmission and hardware on smartphones. As of 2024 this led to over 4 billion smartphones users worldwide (Statista, 2024). Unfortunately most of the communication methods used on smartphones all rely on mediators. Be it a router in a local network or a cell tower in a cellular network, without these nodes a connection between two peers can not be established, no matter how close neighboring devices may be. However in scenarios where the required infrastructure is not available or data needs to be handled sensitive, communication between two mobile devices can be established via Bluetooth or peer-to-peer WiFi since these do not required pre-existing infrastructure and purely rely on local radio broadcast. Due to the latest advancements

in these technologies and smartphone hardware, it is unclear how good direct P2P networks work under certain conditions. This thesis tries to find and measure metrics that indicate the quality of direct P2P connections on Apple's mobile devices. This can help to evaluate the feasibility of projects that are planning to build on these technologies. In particular the Multipeer Connectivity Framework accessible from iOS 7.0+ will be tested for its robustness considering metrics of quality in different scenarios and under different conditions.

Use cases. Like already mentioned in **Motivation**, direct P2P technologies leverage ad-hoc networks to enable communication even when no infrastructure is available. Reasons can vary from environmental disasters to the lack of coverage in less developed countries or instances of governmental censorship. In addition to facilitating communication, this technology can also be employed in location based services. For example, advertising based on proximity to an upcoming football match, or social media that could tell the user about nearby friends without the necessity to access GPS data. TODO… a bit MORE Usecases, because there are actually a lot. Moreover, confirming to a well defined protocol could also improve interoperability between apps, where social media applications could benefit from advertising proximity beacons of nearby independent shops.

1.2 Research Definition

Research Questions

The question this thesis tries to answer is if direct P2P connections between Apple devices can improve connectivity in contrast to commercial infrastructure technologies? This should help to answer if new forms of mobile connections can already be approached and if they should be futher investigated and improved.

Hypothesis

H_1

Direct P2P connections on Apple devices can enhance connectivity in different scenarios and therefore work as an alternative to mediator based communication technologies.

H_2

Direct P2P connections on Apple devices have more bandwidth than the average bandwidth in modern 5G technologies.

Method

A prototype application will be developed that will serve as a tool to measure the quality of the connection. The metrics will be defined in the test protocol in Section 5. In addition, different testing scenarios, indicating various characteristics of real life scenarios will be tested to cover most areas of application. Measurement of connection quality will be purely based on values captured by the prototype app itself. The characteristics of the environment will be first described based on human perceive and depending on the environment measured with suitable methods. The distance between the devices will always be measured using…

1.3 Summary

Since the latest smartphones have improved hardware and operating system support for direct P2P, it is unclear how well these technologies can currently serve direct communication under different conditions. Focusing on the Apple platform, an iOS application is developed, that serves as testing utility. After discussing related work that summarizes past attempts, considerations and benefits of direct communication in Section 2, Section 3 will provide all required knowledge to understand the concepts of the design and decisions made to best answer if or when latest technology is/will be ready to rely on direct P2P communication.

2 | Related Work

Already back 2001 the Proem project (Kortuem, Schneider, Preuitt, *et al.*, 2002) examined different aspects of peer-to-peer applications for ad hoc networks. They already noticed the trend for a ever-larger becoming applicability of personal mobile devices for data sharing but listed resources of mobile devices among other possible limitations. This facet has fastly changed since then and several new ideas like ShAir (Dubois, Bando, Watanabe, *et al.*, 2013), a middleware infrasructure for peer-to-peer sharing between mobile devices or mFerio (Balan, Ramasubbu, Prakobphol, *et al.*, 2009), a peer-to-peer mobile payment system have emerged. The working group of mFerio already noticed the problem that mobile devices rely too heavily on static infrastructure. Fortunately hardware of modern smartphones has matured and has gotten support for Bluetooth, WiFi Direct and Apple's Multipeer Connectivity, which were used by Newport in his approach to develop a new gossip algorithm for a local peer to peer communication system (2017). Though approaches existed to also introduce LTE-Direct, no support for this technology is given on mobile smartphones (Condoluci, Militano, Orsino, *et al.*, 2015). This is why this thesis will focus on the available technologies WiFi-Direct and Bluetooth, which work under the hood of Apple's Multipeer Connectivity.

TODO: LTE Direct mystery and 5G NR sidelink mystery, why do mobile phones not have access to these technologies? at least the app developers do not have access to that most of this technology is used in vehicles and autonomous driving, C-V2X, seems like these direct communication technologies are not available on modern smartphones and mostly used in public safety or automotive applications, look for sources and write a paragraph about this and its use cases

TODO: write a paragraph about newer approaches about wifi direct or bluetooth on smartphones and mobile devices

This paragraph is just to showcase that i am capable of both including code listings in Section 5 and also reference them correctly in other parts of the thesis. Listing 1 shows how important it is to be very alert when dealing with concurrency.

3 | Background

Describe that all of mobile connections use mediators and why this happend like it and why it is beneficial (bigger antennas that can handle weaker signals and send stronger signals) describe what has changes in the last years on apples platform and why non-mediator communication got so important for apples ecosystem, apple watch pairing, clone app to mac (when opened on iphone, eg. calendar), cmd+c and cmd+v via across iphone and mac what is lorawan and how could it be used one day in smartphones and mobile computing describe why peertopeer wlan or bluetooth is not yet suitable for long distance communications, also mention the longest wlan connection, 273km with bigger antennas

TODO: Maybe swap out background and related work

In the background section you might give explanations which are necessary to read the remainder of the thesis. For example define and/or explain the terms used. Optionally, you might provide a glossary (index of terms used with/without explanations).

Hints for equations in Typst:

Mathematical formulas are (embedded in $) in Typst. For example:

The notation used for **calculating** of *code performance* might typically look like shown in Equation 1, i.e. the first one for **slow** in Eq. I and the other one for **very slow** in Eq. II.

$$O(n) = n^2 \tag{I}$$

$$O(n) = 2^n \tag{II}$$

Equation 1: Equations calculate the performance.

In the text we refer multiple times to ϕ. We define it to be calcultated as shown here:

$$\begin{aligned} d &= 24 - 10 - 7 - \sqrt{3} \\ d &= 14 - 7 - \sqrt{3} \\ d &= 7 - \sqrt{3} \end{aligned} \tag{III}$$

$$\phi := \frac{d}{3} \tag{IV}$$

Equation 2: A custom definition of ϕ allows to shorten upcoming equations.

The Equation 2 explains (for the single steps see Eq. III and Eq. IV) how the overall ϕ is calculated to be used in the upcoming formulas of this thesis.

4 | Concept

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describe the overall concept of what you have planned

what is the purpose of the app, how are you planning to measure the metrics and implement these measurements in the app

maybe describe which metrics you want to test, but this goes a bit too far into implementation

maybe describe in general your approach to a test protocol and that you want to test it in different scenarios and why you think that these different scenarios are important and how you plan to visiualize the results,

Describe an overall concept of a solution, which could possibly solve a given problem. Design a novel solution and visualise the architecture and relevant (data) flows. Compare and relate your approach to possible alternatives and argue why and in which way(s) the suggested solution(s) will be better.

Hints for formatting in Typst:

1. You can use built-in styles:
   1. with underscore (_) to *emphasise* text
   2. forward dash (`) for `monospaced` text
   3. asterisk (*) for **strong** (bold) text

You can create and use your own (custom) formatting macros:

1. check out the custom style (see in file `lib.typ`):
   1. `#textit` for *italic* text
   2. `#textbf` for **bold face** text

5 | Implementation

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```
let task0 = Task { @MainActor in
    for await nearbyPeers in service.nearbyPeersToInvite.values {
        state.nearbyPeersToInvite = nearbyPeers
    }
}

tasks.insert(task0)
```

Listing 1: Saving the reference to the detached task, so it can be canceled when the viewmodel is dereferenced.

https://developer.apple.com/documentation/swift/calling-functions-with-pointer-parameters how to pass pointers to functions

Describe what is relevant and special about your working prototype. State how single features help to solve problem(s) at hand. You might implement only the most relevant features. Features you select from your prioritised feature list assembled in Chapter 4. Focus novel, difficult, or innovative aspects of your prototype. Add visuals such as architectures, diagrams, flows, tables, screenshots to illustrate your work. Select interesting code snippets, e.g. of somewhat complicated algorithms, to present them as source code listings.

For example, you might explain your overall system, then the details of the backend and frontend development in subsections as shown here:

5.1 Overall System

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Hints for images in Typst

Use vector graphic formats such as Scalable Vector Graphics (SVG) for drawings and png for screenshots. Using jpeg is only ok, if you need to show photographic images, such as a picture of a sunset.

For example, the following shows how an SVG image is references using the `image` Typst macro. The image is furthermore embedded in a `figure` macro. The `flex-caption` allows to include a full sentence as caption below the image and a short caption for the list of figures. Also note the use of a label `<fig:companylogo>` which is later referenced with `@fig:companylogo`:

Figure 1: The logo of the FH JOANNEUM, the University of Applied Sciences.

The application uses the logo of the company, see Figure 1, in the navigation bar to provide *home* functionality.

5.2 Testing Protocol

What do I want to achieve? I want to test different scenarios, so I know which transport protocol performs best under certain circumstances and environments. I want to test different payload sizes, package count from perspective of !application level!. The metrics should be captured depending on distance and other environmental factors like obstacles.

capture: distance obstacles outside temperature

different scenarious: underground forrest city field

do these different scenarios with: 100/1000/10_000/100_000 packages 128/4096/16_384 byte per package 1m/10m/30m/maxm

do every case 5 times, max meters are not done in every scenario, just how far it can go...

also include seperately a comparison between tcp options, noDelay and noPush

done -> inPr -> notStarted code -> test -> write thesis

5.3 Backend

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Hints for code listings in Typst:

The way to include source code in your document is discussed and shown in https://typst.app/docs/reference/text/raw/. For this template we provide a custom macro/function *fhjcode* to support listings with code pulled in from external files and with line numbering. For example:

For example: We implemented a minimal *script* in Python to manage a secure `Messages` in object oriented ways. See Listing 2 and Listing 3 for a minimal `SecureMessage` class.

```
class Message:
    def __init__(self,txt):
        self.m=txt
    def __str__(self):
        return f"{self.m}"
```

Listing 2: Defining a base class in Python. Here, the base class is named *Message*.

```
class SecureMessage(Message):
    pass
```

Listing 3: For inheritance we might define a specialised class based on another class. Here, the specialised class *SecureMessage* is based on the class *Message*.

For example: As shown in Listing 3 the secure version of the class is just a stub where further improvements and extensions have to be applied.

5.4 Frontend

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Hints for abbreviations and glossary entries *gls(key)* in Typst:

Abbreviations should be written in full length on the first occurrence. Later the short version can be used. Therefore, define glossary entries with a *key* and a *short* as well as a *long* description first (see file *glossary.typ*). In the text you might use `#gls(<key>)` (and `#glspl(<key>)` for plural) usage of an abbreviation. For example:

The system is using Copy on Write (COW) for optimisation. The implementation of COW can be changed by … Note the usage of the special configured Garbage Collection (GC). We compared many GCs to find out ..

6 | Evaluation

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Describe (proof) how your implementation really solved the stated problem. I.e. accept or reject your hypotheses. Provide a range of input data sets. Run experiments and gather the output (of tools) to meter your prototype. For the analysis, collect the measurement-data, process (e.g. filter) data and interpret the data. Include an interpretation of the work. What do the results mean to you? State current limitations of your solution. Give (personal) interpretation where suitable. Your own opinion is relevant, but must be marked clearly as such.

6.1 Setup Experiment

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For example: During the setup the GC was configured for the parallel version using the value `+UseParallelGC` for the command line argument `-XX` (`java -XX:+UseParallelGC`).

Hints on dynamically reading in external data for tables in Typst:

Using the custom macro `fhjtable` it is possible to include data dynamically for table generation. The data has to be specified in Comma-separated Values (CSV) as shown below:

Name	Profession	Experience (in years)
Max	Student	3
Mia	UX-Designer	7
Helga	Programmer	9

Table 1: Professional experience of the test users with databases.

Find in Table 1 the years a user has worked with different relational or nosql databases in a professional context.

6.2 Measurement

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Hints on using tables in Typst:

Somewhere in the normal text of the thesis the interpretation of data and information shown in a table must be discussed. Explain to the readers which numbers are important. Possibly, highlight unexpected or special data points.

	Min	**Max**	∅	σ
Network roundtrip time	34.6s	42.5s	38.1s	2.3s
Time for single request	2.4s	13.5s	**7.1s**	4.3s

Table 2: The numbers in the table above show the minimum, maximum, average ∅ , and standard deviation σ of the 273 measured network times in seconds.

For example: … Table 2 shows some calculated results on the roundtrip and request times measured in the experiment. The average, the minimum, the maximum and the standard deviations hint to a dramatic increase (> 13%) in performance in comparison to the old solution of 2003.

6.3 Interpretation of the Data

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For example: The customisation of the GC seem to have following positive and negative consequences....

Hints on dynamic calculation in Typst:

We might calculate, e.g. `#calc.max(...)`, within our document, such as max of three and seven times two is: 14.

Hints on using logic in Typst:

For example, we might use **for loop** to arrange a few images in a grid box, as shown below.

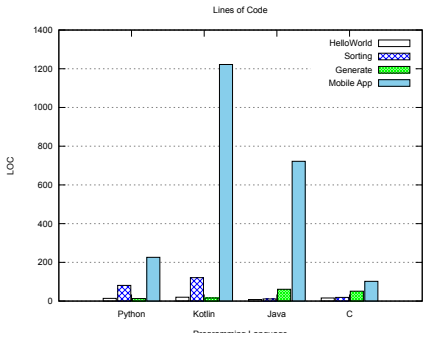

Figure 2: Compared source code by metric 1.

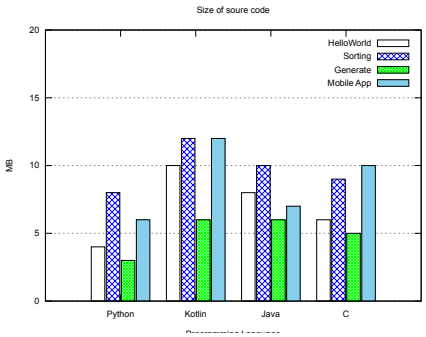

Figure 3: Compared source code by metric 2.

Hints on Charts:

Note: the charts (**vector**! images) shown have been created from raw data using the tool **gnuplot** on the command line. With `gnuplot` you can create charts by use of a textual command language. This is great for automation and it is also great for managing the source code in `git`.

7 | Conclusion and Outlook

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Sum up the results achieved and give an outlook by suggesting further research by explaining how others could built on your results.

Glossary

COW – **Copy on Write** 10

CSV – **Comma-separated Values** 11

GC – **Garbage Collection** 10, 11, 13

P2P – **Peer to Peer** 1, 2, 3

SVG – **Scalable Vector Graphics** 8

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