

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

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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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Contents

List of Figures	iv
List of Tables	v
List of Listings	vi
1 Introduction	1
1.1 Motivation	1
1.2 Research Definition	2
2 Related Work	3
3 Background	4
4 Concept	5
5 Implementation	6
5.1 Overall System	6
5.2 Backend	7
5.3 Frontend	7
6 Evaluation	8
6.1 Setup Experiment	8
6.2 Measurement	9
6.3 Interpretation of the Data	10
7 Conclusion and Outlook	11
Bibliography	13

List of Figures

Figure 1: Company icon provides <i>Home</i> navigation	6
Figure 2: Compared source code by metric 1.	10
Figure 3: Compared source code by metric 2.	10

List of Tables

Table 1: DB expertise in years.	8
Table 2: Roundtrip and request times.	9

List of Listings

Listing 1: Base class <i>Message</i>	7
Listing 2: Specialised class <i>SecureMessage</i>	7

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.

(Calvin 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](#).

1.1 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. Nevertheless the complexity of creating devices supporting all of these different standards at the same time, global economic demand has impacted research and development in data transmission and hardware engineering to accumulate to over 4 billion smartphone users, as of 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 are. However in scenarios where the required infrastructure is not available or data needs to be handled sensitive, communication between two mobile devices can be initiated via Bluetooth or peer-to-peer WiFi. Due to the latest advancements in these technologies and hardware, it is unclear how good of an option it is to replace mediator based with direct [P2P](#) communication in various situations. 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 alike projects. 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 locations.

1.2 Research Definition

Research Questions

Can direct P2P connections between Apple devices improve connectivity in contrast to commercial technologies to build new forms of mobile connections?

Hypothesis

H_1

Direct P2P connectivity on Apple devices can enhance connectivity in different scenarios and therefore work as an alternative to mediator based communication technologies, for implementing ad-hoc mesh networks.

Method

A prototype application will be developed that will serve as a tool to measure quality metrics of connectivity. The metrics will be defined in the test protocol. In addition, different 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. Measuring distance will be done with TODO

Since the latest smartphone technologies improved hardware and operating system for direct communications, it is unclear how well these techniques can currently serve direct communication in different scenarios. Focusing on the Apple platform, an iOS App is developed, that also serves as testing utility. After discussing related work that summarizes past attempts, considerations and benefits of direct communication the Section 3 will provide all required knowledge to understand the concepts of the design and decisions made to best answer the question, 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 (Newport, 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.

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

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 calculatated 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 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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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 referenced 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 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 1 and Listing 2 for a minimal `SecureMessage` class.

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

Listing 1: Defining a base class in Python. Here, the base class is named *Message*.

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

Listing 2: 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 2 the secure version of the class is just a stub where further improvements and extensions have to be applied.

5.3 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	\emptyset	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 \emptyset , 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.

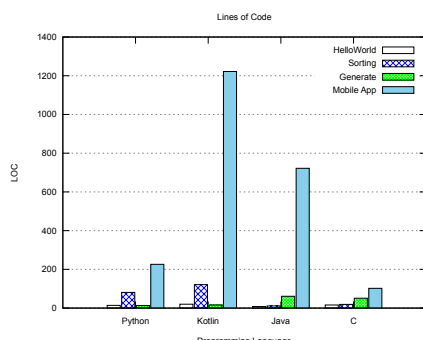


Figure 2: Compared source code by metric 1.

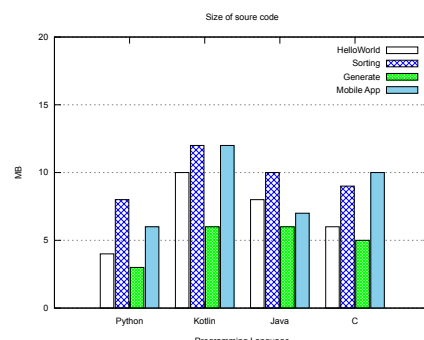


Figure 3: Compared source code by metric 2.

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 7

CSV – Comma-separated Values 8

GC – Garbage Collection 7, 8, 10

P2P – Peer to Peer 1, 2

SVG – Scalable Vector Graphics 6

Bibliography

- Balan, R. K., Ramasubbu, N., Prakobphol, K., Christin, N., et al. (2009) mFerio: the design and evaluation of a peer-to-peer mobile payment system. In: *Proceedings of the 7th international conference on Mobile systems, applications, and services*. [Online]. June 2009 Kraków Poland, ACM. pp. 291–304. DOI:[10.1145/1555816.1555846](https://doi.org/10.1145/1555816.1555846).
- Condoluci, M., Militano, L., Orsino, A., Alonso-Zarate, J., et al. (2015) LTE-direct vs. WiFi-direct for machine-type communications over LTE-A systems. In: *2015 IEEE 26th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*. [Online]. August 2015 Hong Kong, China, IEEE. pp. 2298–2302. DOI:[10.1109/PIMRC.2015.7343681](https://doi.org/10.1109/PIMRC.2015.7343681).
- Dubois, D. J., Bando, Y., Watanabe, K. & Holtzman, H. (2013) ShAir: extensible middleware for mobile peer-to-peer resource sharing. In: *Proceedings of the 2013 9th Joint Meeting on Foundations of Software Engineering*. [Online]. August 2013 Saint Petersburg Russia, ACM. pp. 687–690. DOI:[10.1145/2491411.2494573](https://doi.org/10.1145/2491411.2494573).
- Kortuem, G., Schneider, J., Preuitt, D., Thompson, T., et al. (2002) When peer-to-peer comes face-to-face: collaborative peer-to-peer computing in mobile ad-hoc networks. In: *Proceedings First International Conference on Peer-to-Peer Computing*. [Online]. 2002 Linköping, Sweden, IEEE Comput. Soc. pp. 75–91. DOI:[10.1109/P2P.2001.990429](https://doi.org/10.1109/P2P.2001.990429).
- Newport, C. (2017) Gossip in a Smartphone Peer-to-Peer Network. In: *Proceedings of the ACM Symposium on Principles of Distributed Computing*. [Online]. July 2017 Washington DC USA, ACM. pp. 43–52. DOI:[10.1145/3087801.3087813](https://doi.org/10.1145/3087801.3087813).