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PERFORMANCE STUDY ACROSS WIRELESS INTERFACES ON SMARTPHONES

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Potential of Opportunistic Relaying

PERFORMANCE STUDY ACROSS WIRELESS INTERFACES ON SMARTPHONES

A Dissertation

Submitted to the Graduate School
of the University of Notre Dame
in Partial Fulfillment of the Requirements
for the Degree of

Doctor of Philosophy
in
Computer Science and Engineering

by

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Abstract

by

Shu Liu

To my husband, Wei, who inspires me to exceed my potential.

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PREFACE

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Aaron Striegel, who helped provide direction and guidance for this work. Without his trust and support, I would not have had the opportunity to work in such great research projects. I would also like to thank the members of my committee, Dr. Christian Poellabauer, Dr. David Hachen and Dr. Gregory Madey, for their time and support in this process.

I also need to thank all my colleagues who create such a good atmosphere in the group; Dr. Andrew Blaich, Dr. Yingxin Jiang, Dirk Van Bruggen, Lei Meng, Xueheng Hu, Benjamin Bockdtege, and Rachael Purta. Also Margaret and Michael, deserve a special thanks because their great supports in the Netsense project. I need to further thank all my friends, Nikhil, Hongsheng and Mehrdad, who always took the time to listen.

SYMBOLS

CHAPTER 0

FEATURES OF FORMATTING IN THIS EXAMPLE FILE

This **chapter** has been added to the original sample file to highlight the various features with the formatting that conforms to the Graduate school guidelines — whether obtained due to the use of `NDdiss2 ϵ` class file or just plain good practice.

- An important thing you might notice is that the title of this chapter is not in all CAPS. This is a feature since using `\MakeTextUpperCase{}` is not helpful when you have a math formula or something that just doesn't go CAPS (for eg. elemental symbols).
- If you're looking at a pdf document, the pdf bookmarks (left column) link to all major textual sections including abstract, toc, lof, lot and bibliography.
- In the *dedication*, the title name has been modified. So, you know how to and that it can be done.
- The entries in the *List of figures* and *List of Tables* are single-spaced themselves but are double-spaced from the other.
- The table captions are not in all CAPS as well for the reason mentioned above.
- Appropriate space is left between the **Table xx** and its corresponding caption (which is double-spaced itself) as in table tbl:bogus1 1.1.

- Tables look much better without the vertical lines (good practice).
- There is double-spacing between the table entries but single-spacing within the entry.
- The chapter (see Chapter [2](#)) or section titles are double-spaced as mentioned in the guidelines.
- There is a `subsubsection` present (eg. section [2.1.1.1](#)) and is properly formatted in the TOC.
- Table [A.1](#) is an example of the use of `landscape` environment in which a normal table is formatted in a *landscape* mode.
- The `longtable` environment is used in Tables [2.1](#) and [A.2](#), in normal and `landscape` mode, respectively. The table captions are formatted properly in both cases.
- In the table [2.1](#), the `footnote` in the table header does not appear at all. This is not an error of the `NDdiss2 ϵ` class but of the `longtable` package.
- An example of citing a website is shown in the bibliography (see [gairley2000](#)) which is formatted using the `nddiss2e.bst` citation style file.
- A bit of information on the `NDdiss2 ϵ` class file and the typesetting program used is included in a box on the last page of the thesis.

CHAPTER 1

INTRODUCTION

1.1 Overview

This is an overview of the introduction. In here, I will use many many buzzwords and other legalistic-types of terms, mostly begining on the expounding of the holistic and synergistic energy that Gnus bring to our organizations.

1.1.1 Background

In preparation for reading this dissertation, I would highly recommend reading some of the other material available on Gnus (~~gnus98; gerry_ganst,greenfield96: gettin_know_gnu~~ ~~(??)~~). They are very well written and will give you a fuller understanding of Gnus.

Gnus are frequently mistakes for squirrels. They are not squirrels. They are Gnus. Don't call them squirrels, either (unless you have food in your hand); they tend to get a bit upset.¹ If you have food in your hand, they tend to ignore this insult and accept your food as a peace offering.

1.1.2 Foreground

Table ~~tbl:bogus1~~ 1.1 shows some feeding frequencies for where Gnus like to eat around the Notre Dame campus. Gnus have work weeks, just like humans do, hence the much

¹This is frequently mistaken for the chattering and scampering away. Gnus are actually quite polite; they will leave if they have nothing nice to say, for fear of saying something offensive.

TABLE 1.1

tbl:bogus1

WHERE Gnus LIKE TO EAT

Location	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Front of Dome	1	5	6	5	4	5	1
Stonehenge	2	9	10	12	9	14	2
The Rock	1	3	4	3	4	3	0
The ACC	3	4	5	5	5	4	1
Dining Halls	5	14	12	13	14	12	3
Hesburgh Library	2	3	5	2	3	4	2

lower frequencies on weekends. This can lead us to conclude that Gnu weekend shifts are much smaller than the normal work-week shifts. In fact, we can attempt to parametrize the sighting frequency, \mathcal{F} , by the student population, type of food, and day of the week as:

$$\mathcal{F} = \mathcal{F}(p, f, d). \quad (1.1)$$

Table [tbl:bogus2](#) shows what they typically like to eat.

Figure [fig:bogus3](#) shows a nice graph of location distributions by day of week. I have no real reason for including it except to show that figures work as well. Did I mention that Gnus are really cool?

Gnus typically tend to come out when there are large gatherings of humans with food. Gnus work very hard at providing us with all the things that we like (trees, dirt, air, etc.), and so we should freely give them food. They will come

TABLE 1.2

WHAT Gnus LIKE TO EAT ON THE NOTRE DAME
CAMPUS, LISTED BY AVERAGE NUMBER OF
SIGHTINGS PER WEEKDAY

tbl:bogus2

Food	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Twinkies	1	5	6	5	4	5	1
Ding Dongs	2	9	10	12	9	14	2
Carrots	1	3	4	3	4	3	0
Lettuce	3	4	5	5	5	4	1
Twizlers	5	14	12	13	14	12	3
Jawbreakers	2	3	5	2	3	4	2

Figure 1.1. Location distributions by day of where, where the X axis is the weekday (0 through 6), and the Y axis is the sighting frequency

fig:bogus3

up and stand a respectful distance away from you, waiting to see if they will be rewarded for their efforts. If you offer some food, they will take it and back off a respectful distance in order to consume their food while leaving you to your “personal space.”

1.2 Groovin’ Gnus

sec:groovin-gnus

Gnus do tend to stay away from humans in their normal day-to-day workings. This is mainly because humans don’t, for the most part, understand what they are doing. If a Gnu is working, and a human approaches it, the Gnu will tend to drop whatever it is doing and run away. This is probably do to the tendency for humans to have “group meetings” and “productivity seminars.” Most Gnus are deathly afraid of such overmanagement, and run at the slightest hint of it, for fear that it will cripple their real work.

It is interesting, however, that Gnus have chosen an Institution of Higher Education for their BOO.² It is often said that:

Academic politics are the dirtiest, meanest, ugliest, and generally the most low-down, in-your-face, and kick-em-while-they’re-down than anywhere else (even Washington D.C.) because the stakes are so low.

It has been hypothesized that the Gnus are subtly trying to affect a change for the better (i.e., eliminating the overmanagement problems) by working the very system that they are trying to change, from within. That is, the graduates from Notre Dame can learn from the examples of the Gnus here, and run screaming (or chattering) at the slightest hint of overmanagement, and let the real work proceed unhindered.

²Base of Operations.

CHAPTER 2

GNU THINGS ARE GOOD THINGS FOR ALL GRADUATE STUDENTS OR
SO IT SEEMS`chap:golfing`2.1 Gnu See, Gnu Do, Gnu Goes Golfing with Green Golf Genes and Gesticulates
Grapes

So why do gnus do what they do? This is a perennial question that has yet to be answered definitively by scientists. Is their future somehow tied inexplicably with that of humans? Hard to say, but we do feed them a lot. It has even been theorized that rotundness is a symbol of status or class within the Gnus; those who are more productive (i.e., cute, furry, friendly) will be fed more than those who are less so. So the more rotund, the higher status one has in the Gnu society.

One could extrapolate this to mean that there is a super-Gnu out there somewhere; the biggest, roughest Gnu that you've ever seen, probably of epic proportions! This would have to be the Leader of Gnus, or LoG for short. But the LoG would definitely have to be the cutest, furriest, and most friendly Gnu that you've ever seen.

2.1.1 The LoG

So how does the LoG get chosen? Ultimately by humans. So we can say that the Gnu society is perhaps the truest democracy that has ever existed; the

leader is chosen by merit, and chosen by complete outsiders. As such, the LoG must truly epitomize all that Gnus stand for: opposedness to overmanagement, cuteness, friendliness, and furriness ([gloonson98:_gnuly_discov_gnus](#)). The gnus themselves vote at an annual election, based upon these attributes (campagaining is an anethema to Gnus; see Section [sec:groovin-gnus](#) 1.2).

[sec:data](#) 2.1.1.1 Election Data

Table [tbl:votes](#) 2.1 shows the latest electoral college voting by the LoG for the year 2000. Each Gnu is scored on a scale of one to ten on the attributes described above. The results shown in the table are average scores in each category for all votes; the Gnu's final score is shown in the final column.

TABLE 2.1

ELECTORAL COLLEGE RESULTS FOR THE LoG ELECTION IN

[tbl:votes](#)

THE YEAR 2000

Candidate ¹	Anti-management	Cuteness	Friendliness	Furriness	Aggregate
Glen	6.2	7.0	6.1	9.8	7.2
Goober	6.9	2.1	5.7	4.1	4.6
Genevra	2.2	2.0	1.1	1.1	1.6
Greg	8.3	0.4	1.1	9.5	4.8
Gina	6.0	7.8	6.4	4.9	6.2
Geof	1.1	8.7	3.7	7.3	5.2
Grendel	2.8	1.7	3.4	3.2	2.7
Geronimo	1.2	1.2	8.8	2.2	3.3

TABLE 2.1

Continued

Candidate	Anti-management	Cuteness	Friendliness	Furriness	Aggregate
Gabrielle	4.7	3.6	0.8	2.0	2.7
Giovani	8.4	5.8	3.4	7.4	6.2
Graham	4.7	5.8	5.3	0	3.9
Gil	5.9	4.0	5.5	7.6	5.7
Gerald	2.0	3.7	8.0	4.3	4.5
Guilani	7.7	3.9	2.7	6.4	5.1
Guido	7.6	4.3	6.5	1.0	4.8
Godzilla	5.1	2.2	5.3	6.9	4.8
Gail	5.7	7.9	4.1	1.0	4.6
Garth	4.7	7.1	2.5	3.0	4.3
Gavin	1.1	9.5	0.4	8.0	4.7
George	9.5	4.5	9.1	7.5	7.6
Gunnar	1.4	5.8	4.8	6.2	4.5
Gillian	7.6	9.0	6.4	4.6	6.9
Greta	1.5	0.5	0.9	7.7	2.6
Gabby	1.2	3.3	7.0	2.1	3.4
Gaetena	6.8	1.9	4.1	8.3	5.2
Ganet	2.3	1.1	8.5	7.3	4.8
Gardenia	1.8	9.5	9.9	3.0	6.0
Genna	5.2	3.7	3.4	3.8	4.0

TABLE 2.1

Continued

Candidate	Anti-management	Cuteness	Friendliness	Furriness	Aggregate
Genesis	1.7	8.3	6.7	4.9	5.4
Genaveve	4.7	8.9	3.4	9.2	6.5
Gene	3.3	6.9	0.6	5.5	4.0
Gilda	5.2	4.6	9.9	1.4	5.2
Goldie	8.9	9.1	2.0	8.2	7.0
Grace	5.9	3.2	3.1	4.3	4.1
Gretchen	4.5	6.5	1.6	1.3	3.4
Garrick	4.8	5.7	9.4	5.1	6.2
Gallagher	7.4	0.4	7.6	0.4	3.9
Gerry	1.4	8.8	4.7	0.5	3.8
Gertrude	9.1	8.3	0.4	5.5	5.8
Gehosephet	6.6	2.9	8.3	4.4	5.5
Gohn	8.7	2.6	7.4	2.3	5.2
Gibby	8.7	6.9	4.7	7.2	6.9

As you can see from Table ^{tbl:votes}2.1, George (my favorite Gnu) won for the year 2000, with an aggregate score of 7.6.

APPENDIX A

GNU GENERALISMS

A.1 Definitions

Several definitions are presented in Table ^{tbl:defs}A.1 to show both how to do rotated, line-spanning tables, as well as to define some commonly used Gnu terms.

tbl:defs

TABLE A.1
COMMONLY USED Gnu TERMS

Term	Definition
Gnu	Small furry animal that is related to the squirrel (although they won't admit it).
LoG	Abbreviation for the "Leader of Gnus". See Chapter 2 . ^{chap:golfing}
Twizzlers	Red, twisty candy that is among the most favorite of Gnu foods. Gnus frequently appear overly cute and friendly to humans bearing twizzler packages. This is known as "trolling for twizzlers" among the Gnus.

Finally, Table ^{tbl:rotated-rankings}A.2 shows the top ten Gnus from Table ^{tbl:votes}2.1 ranked in order by their aggregate score (along with some of the raters' comments). This follows a long-standing Gnu tradition of self-improvement through public announcement of score (which some associate with military origins (^{galmira98: gnus_milit}?)). Indeed, this very table has been observed in the Gnu lodge where it was posted for peer review (^{gairley2000}?).

TABLE A.2
TOP TEN Gnus FROM TABLE 2.1 WITH REVIEWER
COMMENTS. Gnus ARE LISTED BELOW IN
ALPHABETIC ORDER.

tbl:rotated-rankings

Candidate	Aggregate score	Reviewer Comments
George	7.6	George is an excellent candidate for the LoG. Slightly low C, but hopefully, this 7.6 will be high enough!
Glen	7.2	A little weak on AM and Fr, but good scores overall. One or two more years of experience should be enough.
Goldie	7.0	Dismal score in Fr; suspect it had something to do with strenuous weight loss program this past year.
Gillian	6.9	Excellent C, but a little shabby on the Fu. Suggest more roughage.
Gibby	6.9	Reasonable scores, but need to work on Fr. Gibby is definitely not a morning Gnu.
Genaveve	6.5	Very low Fr; perhaps more coffee? Suggest practicing “cute faces” in the mirror several hours per day.

TABLE A.2

Continued

Candidate	Aggregate score	Reviewer Comments
Giovani	6.2	Very low Fr; suspect hanging out with Genaveve too much.
Gina	6.2	Mediocre Fu, somewhat low AM. Perhaps a future in marketing or advertising?
Garrick	6.2	Fairly low AM. Fu could be better as well; buy a comb. And a mirror. Immediately.
Gardenia	6.0	Dismal AM; very low Fu. Seems to care more about meeting agendas than personal appearance.

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