SUBJECT

WIRELESS NETWORKS

SESSION 8 Mobility management

Mobility Management" **Mobility management** is one of the major functions of a GSM or a UMTS network that allows mobile phones to work. The aim of mobility management is to track where the subscribers are, allowing calls, SMS and other mobile phone services to be delivered to them.

Contents

Location update procedure

A GSM or UMTS network, like all cellular networks, is basically a radio network of individual cells, known as base stations. Each base station covers a small geographical area which is part of a uniquely identified location area. By integrating the coverage of each of these base stations, a cellular network provides a radio coverage over a much wider area. A group of base stations is named a location area, or a routing area.

The location update procedure allows a mobile device to inform the cellular network, whenever it moves from one location area to the next. Mobiles are responsible for detecting location area codes. When a mobile finds that the location area code is different from its last update, it performs another update by sending to the network, a location update request, together with its previous location, and its Temporary Mobile Subscriber Identity (**TMSI**).

There are several reasons why a mobile may provide updated location information to the network. Whenever a mobile is switched on or off, the network may require it to perform an IMSI attach or IMSI detach location update procedure. Also, each mobile is required to regularly report its location at a set time interval using a **periodic location update**procedure. Whenever a mobile moves from one location area to the next while not on a call, a **random location update** is required. This is also required of a stationary mobile that reselects coverage from a cell in a different location area, because of signal fade. Thus a subscriber has reliable access to the network and may be reached with a call, while enjoying the freedom of mobility within the whole coverage area.

When a subscriber is paged in an attempt to deliver a call or SMS and the subscriber does not reply to that page then the subscriber is marked as absent in both the Mobile Switching Center / Visitor Location Register (MSC/VLR) and the Home Location Register (HLR) (Mobile not reachable flag MNRF is set). The next time the mobile performs a location update the HLR is updated and the mobile not reachable flag is cleared.

TMSI

The Temporary Mobile Subscriber Identity (TMSI) is the identity that is most commonly sent between the mobile and the network. TMSI is randomly assigned by the VLR to every mobile in the area, the moment it is switched on. The number is local to a location area, and so it has to be updated each time the mobile moves to a new geographical area.

The network can also change the TMSI of the mobile at any time. And it normally does so, in order to avoid the subscriber from being identified, and tracked by eavesdroppers on the radio interface. This makes it difficult to trace which mobile is which, except briefly, when the mobile is just switched on, or when the data in the mobile becomes invalid for one reason or another. At that point, the global "international mobile subscriber identity" (IMSI) must be sent to the network. The IMSI is sent as rarely as possible, to avoid it being identified and tracked.

A key use of the TMSI is in paging a mobile. "Paging" is the one-to-one communication between the mobile and the base station. The most important use of broadcast information is to set up channels for "paging". Every cellular system has a broadcast mechanism to distribute such information to a plurality of mobiles.

Size of TMSI is 4 octet with full hex digits and can't be all 1 because the SIM uses 4 octets with all bits equal to 1 to indicate that no valid TMSI is available.[1]

Roaming

Roaming is one of the fundamental mobility management procedures of all cellular networks. Roaming is defined[2] as the ability for a cellular customer to automatically make and receive voice calls, send and receive data, or access other services, including home data services, when travelling outside the geographical coverage area of the home network, by means of using a visited network. This can be done by using a communication terminal or else just by using the subscriber identity in the visited network. Roaming is technically

supported by a mobility
management, authentication, authorization and billing procedures.

Location area

A "location area" is a set of base stations that are grouped together to optimise signalling. Typically, tens or even hundreds of base stations share a single Base Station Controller (BSC) in GSM, or a Radio Network Controller (RNC) in UMTS, the intelligence behind the base stations. The BSC handles allocation of radio channels, receives measurements from the mobile phones, controls handovers from base station to base station.

To each location area, a unique number called a "location area code" is assigned. The location area code is broadcast by each base station, known as a "base transceiver station" BTS in GSM, or a Node B in UMTS, at regular intervals.

If the location areas are very large, there will be many mobiles operating simultaneously, resulting in very high paging traffic, as every paging request has to be broadcast to every base station in the location area. This wastes bandwidth and power on the mobile, by requiring it to listen for broadcast messages too much of the time. If on the other hand, there are too many small location areas, the mobile must contact the network very often for changes of location, which will also drain the mobile's battery. A balance has therefore to be struck

Routing area

The routing area is the PS domain equivalent of the location area. A "routing area" is normally a subdivision of a "location area". Routing areas are used by mobiles which areGPRS-attached. GPRS is optimized for "bursty" data communication services, such as wireless internet/intranet, and multimedia services. It is also known as GSM-IP ("Internet Protocol") because it will connect users directly to Internet Service Providers

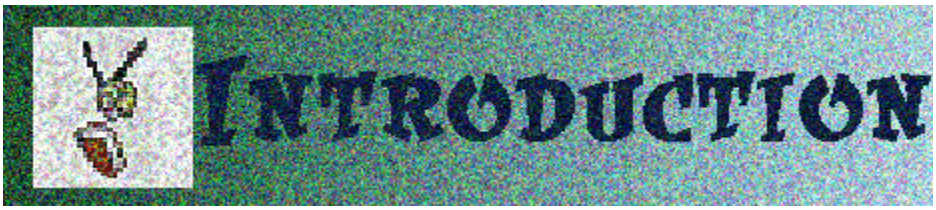
The bursty nature of packet traffic means that more paging messages are expected per mobile, and so it is worth knowing the location of the mobile more accurately than it would be with traditional circuit-switched traffic. A change from routing area to routing area (called a "Routing Area Update") is done in an almost identical way to a change from location area to location area. The main differences are that the "Serving GPRS Support Node" (SGSN) is the element involved.

Tracking area

The tracking area is the LTE counterpart of the location area and routing area. A tracking area is a set of cells. Tracking areas can be grouped into lists of tracking areas (TA lists), which can be configured on the User Equipment (UE). Tracking area updates are performed periodically or when the UE moves to a tracking area that is not included in its TA list.

Operators can allocate different TA lists to different UEs. This can avoid signaling peaks in some conditions: for instance, the UEs of passengers of a train may not perform tracking area updates simultaneously.

On the network side, the involved element is the Mobility Management Entity (MME). MME configures TA lists using NAS messages like Attach Accept, TAU Accept or GUTI Reallocation Command.



\

An Introduction to the Project/ CASE STUDY

The Social Behavior of Polistine Wasps Project is based on data collected on six nests located in Texas' Brazos Bend State Park with the permission of Texas Parks

and Wildlife (Permits 36-93, 60-95) in May 1994 for *Polistes bellicosus* and March and April 1995 for *P. carolina*.

The nests of *Polistes bellicosus* were videotaped over a four day period shortly after worker emergence. Before videotaping the nests, nearly every wasp was marked using spots of various colors of paint in order to distinguish individuals. In the first half of the videotaping period, nests were left undisturbed. After three days, the queen was removed and the nests were again videotaped.

The nests of *P. carolina* were videotaped before worker emergence when the nests had just eggs or eggs and larvae. The tapes cover periods before and after we removed some of the eggs from the nest.

After recording the behavioral videotape, all wasps still on the nest were collected (missing wasps died between video and collection). Each of the marked wasps was assigned a number, photographed, and later dissected. Before dissection, the head size of each of the wasps was measured. Upon dissection, the ovaries of each of the wasps were removed and photographed. Following dissection, microsatellites were used to determine maternity and genetic relatedness.

In the following projects, you will be expected to use components of all of the collected data in order to determine the social structure of the colony, the importance of variation among the wasps, and, if you have the videotapes of the nest, the effect of the social structure on individual behavior. Throughout the project, you should attempt to make connections between the various types of data. Scientists must continuously interpret data and be able to make connections between the results of different data, projects, and experiments. Once they make these connections, they are then expected to be able to coherently and precisely present their results. As science researchers, you should look at the questions as a stimulus for conducting your own research based on the data provided. Your assignment will ask you to test a specific hypothesis, but exactly how you use the data to test it is up to you. You must also decide what specific predictions to test, and when to reject your test of a prediction as being inadequate and when to reject the prediction and maybe the whole hypothesis. Do not assume the hypothesis is true and just explain away any problems with your test.

Assignments

Below, you will see several different projects in which students have participated. The first assignments are various versions that have been used by Professor Joan Strassmann in her Animal Behavior (Bios321) class at Rice

University. The project was an application of the ideas covered in class and was first used in 1994. The project emphasizes a student's ability to work in a group to test hypotheses.

The next assignment, presented to eleventh and twelfth graders at the South Texas Science Academy in Mercedes, Texas, focuses on developing observation and analysis skills. Students were asked to select three questions which they wished to explore. This choice encouraged them to individually chose the research path they would follow and to focus on a particular problem, giving them a sense of responsibility for the ultimate outcome of the project.

The final set of questions were given to fifth graders participating in Take Your Daughters to Work Day at Rice University. The questions are designed to develop observation skills.

Rice University Animal Behavior (Bios321)

Reproductive Skew in *Polistes*

In this case study I would like you to test the hypothesis of reproductive skew. This theory offers an explanation for how reproduction is partitioned in small societies of individuals who might each reproduce on their own. It assumes that there is a dominant individual that is in control, and that she offers some reproduction to other group members in order to both keep them from leaving (staying incentives) and keep them from challenging her too much (peace incentives). The size of these incentives is predicted from kin selection theory and is based on several factors. If individuals are more closely related, the incentive can be smaller because they can pass on genes through the dominant. If the dominant is a lot larger than the subordinates the incentive can be smaller because they won't win if they challenge her. If it is hard to nest alone, the incentive can be smaller since the subordinates won't have other options. You may come up with other testable predictions of the theory from the readings, or your own discussions. More details on the theory and examples of the tests are in the readings provided to you. You can gather data to test this hypothesis from the videotapes and at the website. You have three nests of two species and so can compare them and see if the hypothesis is supported or rejected in both species and why. Use the following papers for background on skew theory, examples of skew tests and natural history of*Polistes.*

Since *P. carolina* nests in dark boxes and hollow trees and *P. bellicosus* nests on brambles, bushes and grasses in prairies, other opportunities for nesting are much greater for *P. bellicosus* than they are for *P. carolina.* Thus you should treat

ecological constraints as high in *P. carolina* and low in *P. bellicosus.* Remember that in a test of a hypothesis you may find support for it or you may reject it. You may also support some parts and not others. When you reject a hypothesis, it is good to try to come up with an alternative hypothesis that seems more reasonable, though this one is not necessarily tested since you may not have gathered the data for it. This is presented in the discussion section.

To test the skew hypothesis you will need to figure out a number of things including the following.

1. What is genetic relatedness among foundresses on a colony? Does it vary among colonies? What is average genetic relatedness among foundresses in a colony for each species?

2. How is reproduction divided up in the group of foundresses?

3. How is the work of the colony divided up? Foraging, especially for caterpillar is a very risky job.

4. What kind of social conflict is there? Is it greater where you would expected it to be greater according to skew theory?

Put the honor code on the assignment. Work with your study group, divide up work, share data, figures and tables within the group. Don't share text or outlines of the results, though discussions by email are ok. Share only discussion with members of different study groups. It is part of the honor code to tell in a paragraph at the beginning how you divided up the work, and to attribute each figure or table to its authors. Please put a more realistic honor code for this assignment than that you gave no aid, maybe no unauthorized aid...

Data sources:

This project involves testing hypotheses using data from the videotapes on reserve at the library and at the website http://www.rice.edu/wasps. There are images of the heads and ovaries and DNA microsatellites of wasps from three nests of *Polistes bellicosus* and *Polistes carolina.* These data were collected in the spring of 1994 and 1995 at Brazos Bend State Park. On the *P. bellicosus nests,* there are two types of wasps, foundresses who have mated and overwintered, and the first generation of progeny, generally workers. On the *P. carolina* nests there are only foundresses. To do the relatedness estimations you will need the background frequencies of alleles. These are given in a table in the relatedness section. For the alleles of the wasps in the study, score the autorad images of DNA microsatellites. Again, everything should be explained in the web site. Use the bulletin board for questions.

Behavior: On reserve at the library are 3 videotapes from *P. carolina* colonies 14, 35, and 39. On the tapes are behaviors before and after we removed some eggs from the nest, but we will not be using this particular difference in this work. There are also 6 videotapes from *P. bellicosus* colonies 64, 114, and 155. The first three are before we removed the queen and the second, set with later dates are after we removed the queen. You do not need to use the ones from after we removed the queen. The *P. carolina* nests are taped earlier in the season before there were any workers while the *P. bellicosus* nests were taped after the first workers hatched out. These workers are the first brood of the colonies, and are analogous to the oldest brood or larvae in the *P. carolina* nests.

Genotypes: You have genotypes for all the foundresses and workers of *P. bellicosus,* and for the foundresses, larvae and eggs for *P. carolina.* These genotypes can be used to assess genetic relatedness among individuals. They can also be used to determine which of the foundresses produced which of the young. We have computer programs which help with both tasks, and they can be done by hand.

Head sizes: Head size can be used as an overall indicator of size. Head sizes are available for all foundresses on the website for *P. bellicosus*. I will give you the head sizes of *P. carolina.* At the website are the pictures of the marks on *P. carolina* so you can tell them apart.

Ovaries: Images of the ovaries are available at the website too. Unlaid eggs are clearly visible in some of the ovaries. Obviously these were taken at the end of the study, and so may not reflect their earlier condition. All of the foundresses have mated. Though the workers on the *P. bellicosus* nests have not, they can do so should they become queen.

Nest sizes: The number of cells in the nest can be used as an overall indicator of reproductive success of the group. Of course the nests will grow more later in the season, and some will be predated or otherwise die which will reduce their fitness. The adult wasps can rebuild a predated nest since the adults are rarely killed, but of course it sets them back at least a month since that is about how long the brood take to develop.

Order of arrival: We do not know which wasp began the nest for *P. bellicosus.* In *P. carolina*, the first ones at the nest site were wasps 7 on nest 14, 28 on nest 35, and 33 on nest 39. The others came later and at close to the same time.

Sperm: We do not have data from the spermathecae of the queens of P. bellicosus. We do know that each queen only mated once, and that most of

the workers were produced by a single queen, so the sperm allele can be inferred from the workers.

Presentation of your work:

Your work should be presented in the form of a scientific paper addressing a specific set of hypotheses, and prepared in a standard way. You had practice doing this in the first assignment where you wrote everything but the methods and results.

Title: (2 points) This should be a concise, complete description of the study. It should not be too vague or general.

Abstract: (6 points) This should be concise and well-worded. It should make clear what question you addressed and what you found. This paragraph should include a little bit of everything: background, summary of the experiment, results, and discussion. It should NOT include details of the experiment. It shouldn't be more than 6 or 8 sentences long. Many people will read nothing but the abstract, obtaining it on line. It is your chance to hook people into reading the whole paper.

Introduction: (10 points) The introduction should give some background that lets the reader know why the results are important and relevant. It is here that you present the specific hypothesis being tested and what predictions from the hypothesis will be most critically evaluated. You should not summarize methods here. The introduction should provide context, with the briefesp experimental description, so the reader knows how this study fits in with other work. The background should be sufficient, however, to make the reader understand why the different aspects of the study were necessary.

Methods: (7 points) In this section you should be clear about how you analyzed your data to test the hypotheses. You do not need to cover the part actually done in the field or DNA laboratory.

Results: (55 points) Here you present your results as clearly and concisely as possible. Results have the tests of the predictions of the hypothesis. This is not the place for interpretation. If the tests are carefully constructed, the results can be very brief and straightforward. Tables and figures should document all the most important points. Lots of people reading papers look first at the figures. You should not have tons and tons of figures and tables however. Extra data or tables or figures can be put in an appendix, a section that is not required.

Discussion: (20 points) The discussion should create a complete story relating all of the results. You should spend a paragraph, at most, summarizing results, then

go on to discuss the significance of the results. It is here that the reader learns what you think your results have to say about the hypothesis being tested. The discussion section is the researcher's chance to shine and be interesting. If you end up rejecting your hypothesis, or a portion of it, or changing your mind about the relationship between the general hypothesis and the specific predictions, this is the place to tell us. Speculation is good, but be sure the distinction between speculation and results is clear.

General recommendations for writing a successful paper: Read journal articles. This is the best way to get a feel for what is appropriate where. Anthropomorphizing is never acceptable. Don't compare animals to humans; they are too evolutionarily divergent to make these comparisons useful. Be concise. There's no room in journals for lines like "this experiment was carefully planned." The reader will assume that you were careful. Just say what you have to say in the most succinct way possible.

Alternative assignment from 1996:

Paper Wasps as a Model System

After the recordings you have already seen of *Polistes bellicosus*, we removed a dominant female from each of the three colonies and again recorded behaviors. These tapes are available in the library. This assignment is based on these videotapes, the comments on your previous assignment, and on your reading for this class.

1. How does the behavior of *Polistes bellicosus* change after the removal of a dominant female? Are females more or less active? Is there more or less aggression? Is the dominance hierarchy more or less well defined? Is there more or less foraging for food? Do other behaviors associated with bearing or caring change? Are there great differences among the colonies, and why or why not?

2. Who becomes the new dominant female? How can you tell? In whose interests is this? Were your predictions supported? Why or why not? Take into account any comments your instructors made on the first assignment, if this is appropriate.

3. A model system in biology is a system in which important conceptual issues can be tested and the results generalized to other systems. A model system is usually particularly amenable to the study of an important general phenomenon. This might be the case because it involves an animal with short lifespans, or that is easily reared, observed or experimented on, or because it

has been thoroughly studied previously. A model system should be simple and general enough that important concepts can be easily explored and understood. This project has used *Polistes bellicosus* as a model system for kin selection. What are its strengths and weaknesses as a model system? In answering consider similarities and differences of kin selection in wasps and other animals where kin selection has been studied, such as other social insects, dwarf mongooses, naked mole rats, Florida scrub jays, or other animals from your class reading.

Honor code: You are strongly encouraged to work in groups on many aspects of this assignment. You may watch videos, look at data and brainstorm together. You can develop a list of behaviors together. You may generate figures, tables and graphs as a group, or share them within a group only if you have participated in the data analysis that supports each figure, table or graph. Clearly label which figures, tables or graphs you did independently, and which you got from the group. Write a few sentences describing to me how your group worked. Sign the honor code on this assignment. The final text of the report must be done independently!

Alternative assignment from 1994

Three colonies of *Polistes bellicosus* were videotaped in the wild at Brazos Bend State Park for a number of hours. After videotaping, the colonies were collected and the females were measured and genotyped. These videotapes are available from the reserve desk in the library. I also put one set of videotapes in the biosciences computer classroom, where several VCRs are available. These data are available to you over owlnet in a Netscape format in the form of images of the heads (an indicator of size), the ovaries (an indicator of reproductive status) and DNA microsatellites (used to partition reproduction among females and to assess genetic relatedness). This assignment is based on your analysis and interpretation of these data.

1. What do *Polistes bellicosus* females do? Make a complete list of all the behaviors you see performed. This list should be organized by general type of behavior and should have a brief name followed by a longer description. Give a specific place on a tape which you feel is a good example of the behavior. (5 points)

Partial example (from mockingbirds):

- Foraging behaviors
    - Walk-wingflash - Mockingbird walks around on the ground periodically flashing the whites of its wings to scare up insects which it then eats.
    - Perch-hunt - Mockingbird sits in tree and flies out to catch flying insects then returns to tree. there will be lots of others too
- Territorial behaviors
    - Line-walk - Mockingbird walks along edge of territory opposite bird from neighboring territory, displaying by raising its wings and calling.
    - Fight - Mockingbird flies at and crashes into intruder, pecks it on the back continuing for up to 2 minutes.

  etc.

2. How do *Polistes bellicosus* females partition their efforts between reproducing and caring for young? Why? Support your view with appropriate behavioral, ovarian, size or genetic data. You may cite specific locations on the tapes. You may illustrate your answer with figures, tables and graphs. (5 points)

3. How is reproduction divided up in the group of *Polistes bellicosus* females? Why? Support your view with appropriate behavioral, ovarian, size, or genetic data. You may illustrate your answer with figures, tables and graphs. (5 points)

4. If the dominant female is removed who would the foundresses prefer to have assume the role of dominant female? If the dominant female is removed who would the workers prefer to have assume the role of dominant female? Why? Support your view with appropriate behavioral, ovarian, size or genetic data. You may illustrate your answer with figures, tables and graphs. (5 points)

5. Who do you think will actually take over? Why? In whose interests is this? Support your view with appropriate behavioral, ovarian, size or genetic data. You may illustrate your answer with figures, tables and graphs. (5 points)

Honor code: You are strongly encouraged to work in groups on many aspects of this assignment. You may watch videos, look at data and brainstorm together. You can develop a list of behaviors together. You may generate figures, tables and graphs as a group, or share them within a group only if you have participated in the data analysis that supports each figure, table or graph. Clearly label which figures, tables or graphs you did independently, and which

you got from the group. Write a few sentences describing to me how your group worked. Sign the honor code on this assignment. The final text of the report must be done independently!

South Texas Science Academy (High school)
Exploring Social Wasp Behavior

I. Questions based only on videotapes of behavior.

1. What do wasps do?
2. Do some wasps perform certain tasks more often than others?
3. Does the behavior of the foundresses who are mated and have survived the winter differ from the behavior of their daughters who are young and have not mated?
4. How do the wasps build and care for their nest?
5. How do the wasps feed their young?
6. How do the wasps protect their young?
7. How do the wasps clean themselves?
8. How do the wasps interact among themselves?
9. How is the behavior of wasps similar or different among the three colonies?
10. Do wasps on the larger colony bring in more food in all than the smaller colony, or does each wasp on the larger colony simply work less hard?

II. Questions based only on material available at the website.

1. Do foundresses and daughters differ in size or degree of ovarian development? Is this the same for the three colonies? How do you compare ovarian development among wasps?
2. Which foundress has produced most of the daughters? Is there only one queen on all three colonies? Use both microsatellites and ovaries to answer this question.
3. Is the main queen larger than the other foundresses in these three colonies? If not why do you think she is queen anyway?
4. There is one wasp on one nest that could not have been the daughter of any of the females. She was probably a worker that got lost and joined the wrong colony. Which one is she?
5. In wasps, sisters share three quarters of their genes on average. Are the foundresses on the same colony likely to be sisters? Are the daughters on the same colony likely to be sisters? Justify your answer.

III. Questions based on website material and videotapes.

1. Does the main egg layer behave differently from the other foundresses? Justify your answer.
2. Does the wasp who is not related to the others on the nest behave differently from the daughters that were born there? Justify your answer.
3. Do daughters with some ovarian development behave differently from daughters with no ovarian development? Does your answer vary depending on the nest? Justify your answer.
4. Does the largest daughter behave differently from the smallest daughter? Does your answer vary depending on the nest? Justify your answer.
5. Does the largest foundress behave differently from the smallest foundress? Does your answer vary depending on the nest? Justify your answer.
6. If the main egg layer were removed who do you think would take over? Justify your answer.

BRING OUR SON/ DAUGHTERS TO WORK ON WASPS
Electronic Studio Project

1. What do wasps do on their nest?
2. Does the largest female have the largest ovaries?
3. Who is the queen?
4. Does the queen act differently from the other females?
5. Who is unrelated to the egg layers on the nest?
6. Does the unrelated female behave differently from the other females?
7. What else can you figure out about these wasps?