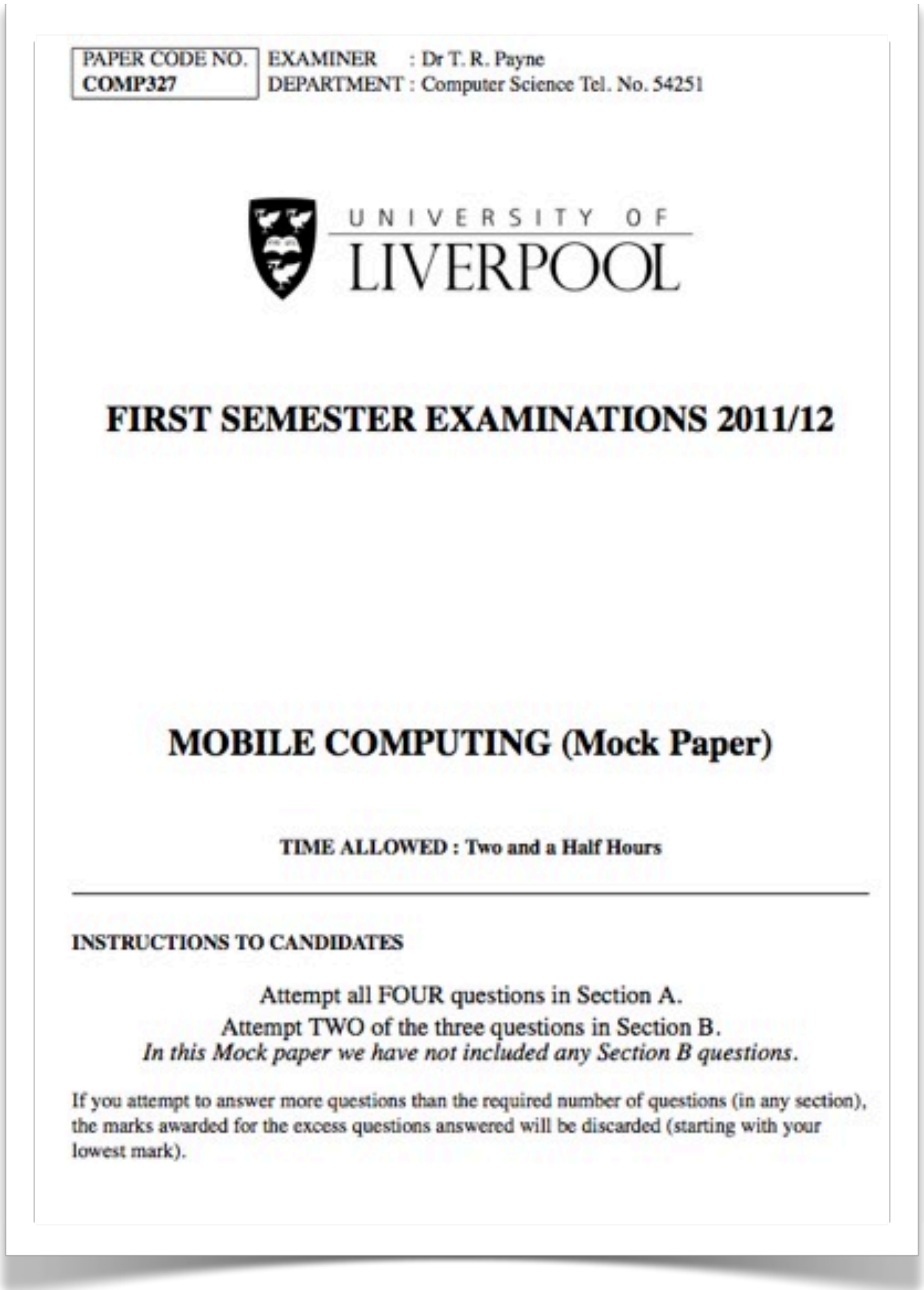
# COMP327
# Mobile Computing

Session: 2011-2012

**Mock Exam Paper (Revision)**

# Exam Paper and Rubric



| PAPER CODE NO. COMP327 | EXAMINER : Dr T. R. Payne<br>DEPARTMENT : Computer Science Tel. No. 54251 |
|---|---|

UNIVERSITY OF LIVERPOOL

**FIRST SEMESTER EXAMINATIONS 2011/12**

**MOBILE COMPUTING (Mock Paper)**

**TIME ALLOWED : Two and a Half Hours**

**INSTRUCTIONS TO CANDIDATES**

Attempt all FOUR questions in Section A.
Attempt TWO of the three questions in Section B.
*In this Mock paper we have not included any Section B questions.*

If you attempt to answer more questions than the required number of questions (in any section), the marks awarded for the excess questions answered will be discarded (starting with your lowest mark).

- The exam paper format has changed from previous years:
  - Section A
    - Complete all four questions, each worth 10 marks
      - Reduced from 5 questions
  - Section B
    - Complete two of three questions, each worth 30 marks
      - Questions are now worth 5 marks more
- Exam is 2 $^{1}/_{2}$ hours long

# Coverage

- Any of the material taught could appear in the exam
- Questions may be
  - Book work (what can you tell me about ...)
  - Discursive (contrast this and that and discuss the pros and cons)
  - Problem solving (given this, what is that)
- Past Papers and Mock Papers are available
  - See Course Web Site
    - Note that there is a typo in Section A Question 5 in 2011

# Typo in 2011 Paper

- There was a typo in Question 5 of Section A in the 2011 paper:

5. Given the following three 8 chip spreading codes, calculate the bits sent by receivers A B and C with the combined transmitted chips (1,1,1,-3,3,-1,-1,-1). Ensure that in your answer, you include all the steps of your calculation.

   - $A_k = 11001100$
   - $B_k = 10101010$
   - $C_k = 10010110$

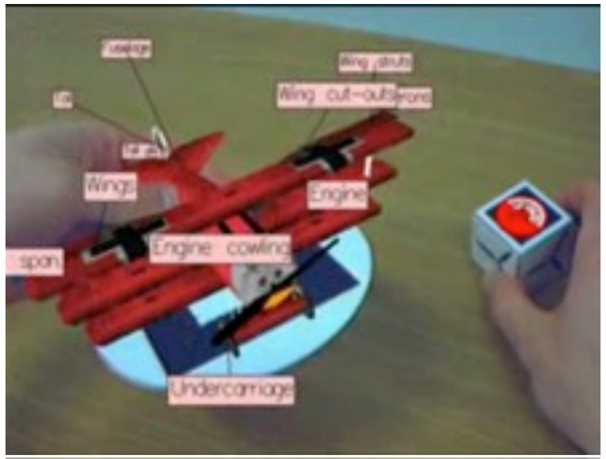
   **(6 marks)**

   A new device, $D$ starts transmitting data, with a spreading code $D_k = 1001101$. If $A$ and $D$ want to send a single data bit whose value is 1, whilst $B$ and $C$ send zero-valued single data bits, what would be the value of the combined transmitted chips received by the UMTS B-Node? **(4 marks)**

- The code $D_k$ was incorrectly stated, with only 7 bits - this should have been 8 bits
  - The correct code was $D_k = 10011101$

# Mock Questions 2011

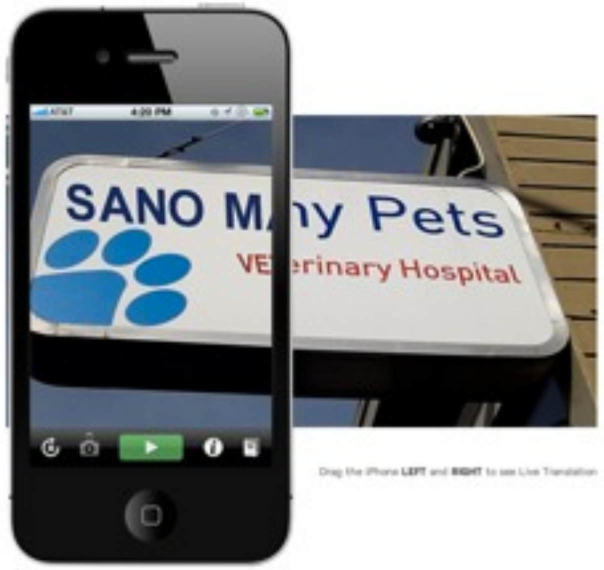
- **Question 1**
  - Discuss three of the primary technological challenges that are faced in developing location-based Augmented Reality applications. Discuss the potential hazards of using such applications on a mobile device, when compared to using such systems within an indoor laboratory environment. (10 marks)




# Augmented Reality

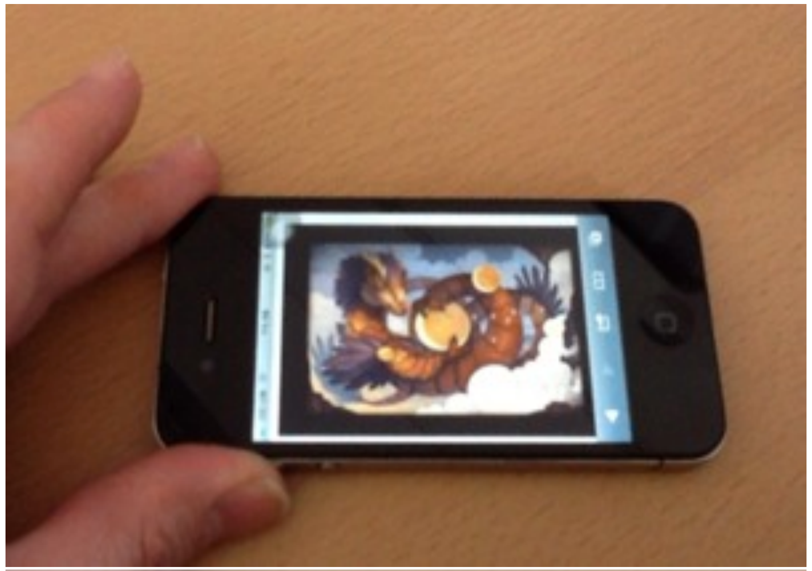

- Combining live direct (or indirect) view of a physical real-world environment with virtual CGI
  - Typically in real-time using the semantics of environmental elements
  - Identify digital "cues" (e.g. 2D barcode) and overlay with a digital image
    - Video camera identifies orientation of the cue, and replaces it with the image, transforming it in 3 dimensions

- Can be used to enhance the environment
  - Provide details about the environment, by "projecting" labels or directions onto the street or building being viewed
- Can be used for entertainment
  - Project games into the real-world, by identifying cues to determine location or features




# Augmented Reality


- To develop augmented reality applications, several technological challenges need to be overcome:
  - Live video is required to project the graphics onto
    - i.e. the app needs to display in real time what the user is looking at, and add the "augmented images" onto that video
  - Positioning information required, to determine relative location of other artefacts that may be annotated
    - Applications that annotate locations or give directions (e.g. Yelp) first need to determine the user's location (using GPS or other location mechanism), device orientation (using accelerometer) and compass direction (using magnetometer) to determine **what** the user is looking at
    - Then the objects that are being looked at need to be presented over the video feed, in the correct position (e.g. building annotations or directions)
  - Image analysis is required to identify cues to overlay graphics
    - Applications such as Word Lens identify text, and replace this with other text corresponding to a translation (e.g. English-Spanish)
    - Other Apps identify patterns (and their orientation) to determine what should be displayed, and in what orientation it should be displayed



# Augmented Reality

- Using Augmented Reality apps in real world (on the go) scenarios can be hazardous!
  - Conventional apps require some attention from reality/environment
    - Users on the go might focus some time on the app, but will also retain awareness of their environment
  - Augmented reality apps provide some awareness of reality/environment
    - Users can be lured into relying on the app to provide that awareness of their environment
- However, this can restrict full awareness, or become fixated on details, and thus act in a dangerous, or unexpected way
  - e.g. loss of peripheral vision etc

# Excellent Solution (10/10)

Location-based augmented reality applications are those applications that determine what should appear on the screen, based on the user's location, the user's orientation (I.e. in what compass direction the user is facing, or holding the device) and the orientation of the device itself (the angle of the device with respect to the horizon, to determine whether the user is facing the ground or looking into the sky). This contrasts with augmented applications that are subject-based, whereby the augmentation is determined by recognising and analysing objects in the video feed.

To develop location-based augmented reality apps, there are several challenges that need to be addressed: three of which include 1) determining what the user is looking at; 2) determining the relative position of other locations which will determine the augmentations on the screen; and 3) overlaying the augmentations on the screen in real time, such that they respond realistically when the device is moved around.

Challenge 1: the device needs to determine the user's location as accurately as possible (ideally using GPS) and their orientation (with respect to magnetic or true north) to determine what the user is looking at. Accuracy is important, especially when the objects being viewed are very close.

Challenge 2: once the users position is known, the relative position of nearby objects can be calculated, in terms of orientation with respect to the user. This means that objects to the north of the user should only produce annotations on the screen when the user is facing in that direction. Proximity may also be used to determine whether or not the annotations should appear (e.g. Only show locations that are nearby rather than far away, or show the closest station in this direction etc).

Challenge 3: a video feed should be obtained from the device's camera, and displayed on the screen. In addition, an annotation should be constructed and inserted into the video feed, in a location that represents the direction the object, without necessarily impairing the users ability to see what is in the environment - I.e. annotations should augment, not obscure the view.

One problem encountered, however, when using such applications is that they are typically relevant on the go (due to their "location"), rather than when used in a safe environment such as in a lab or office. This could be due to the application directing the user to a location, or providing further information about the object the user is viewing (such as landmarks in a city). As such, there is a real danger that the user will loose full awareness of the environment, due to their focussing on the device, or reading the annotations, which could lead to accidents - such as bumping into objects not immediately visible on the screen (e.g. Bollards, or steps).

# Poor Solution (4/10)

The challenges are:

1) determining what the user is looking at, and at what angle
2) determining where other things are, and their relative position
3) creating labels on the screen to point to where the other things are

Hazards could be due to walking into people or other things on the street

- Why is this not so good?
  - The answer simply states the facts, but doesn't explain them or justify them
    - why are these issues challenging?
    - why could the user walk into other people?

# Mock Questions 2011

- **Question 2**
  - The Desktop and Mobile E-Commerce experience can differ wildly. Describe one limitation and one advantage of using a mobile device for e-commerce. (5 marks)
  - Speculate on how RFID sensors could be used to transform a mobile device into a "self-pay" point-of-sales device? How could a store differentiate between legitimate purchases and shoplifted goods? (5 marks)

# Mock Questions 2011

- **Question 2**
  - The Desktop and Mobile E-Commerce experience can differ wildly. Describe one limitation and one advantage of using a mobile device for e-commerce. (5 marks)

**What are the issues?**

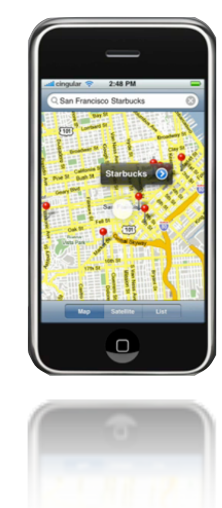
# Mobile Commerce: evolving the E-Commerce Model

**The Desktop Experience**

- Large screen facilitates browsing of large catalogues
  - Requires significant user attention
- Goods can be organised conceptually and displayed graphically
- Significant real estate that can simultaneously support:
  - User context
  - Recommendations to related goods and user feedback
  - Advertising for related goods
  - Multi-column tabular data
- Easy user interaction
  - Facilitates payment through credit card, and providing user details
- Relatively Secure

**The Mobile Experience**

- Context aware
  - Knowledge of the user
  - Knowledge of the environment
  - Requires more autonomy due to restricted user attention
- Capable of interacting with local services and devices
  - Can scan physical goods
  - Can communicate with local services
- Always available and (more increasingly) always connected to the internet
- Existing service agreements through bearer network
  - Can support payment
- Unique identification through SIM and IMEI



**Mobile Devices better suited to some tasks more than others**

# M-Commerce Scenarios

- Augmenting brick-and-mortar commerce
  - Use of RFID or NFC to detect goods
    - Can acquire additional information about the good
      - E.g. product information, price, reviews
      - Additional services such as preview (e.g. for music)
  - Using QR codes to identify, obtain or provide information
    - **Q**uick **R**esponse Code
      - Quicker than URLs; can be captured from billboards or printed media
      - Can encode numeric, alpha-numeric or kanji characters
    - Can display, as well as acquire visual codes
      - Airlines are increasingly using e-ticketing for boarding cards
      - Can use optical scanners to read barcodes from a mobile device
      - Deployments include Spanair, Air France, Lufthansa
- Advantages
  - Informed choice when purchasing goods


# M-Commerce Scenarios

- Electronic Banking, Payment and e-ticketing
  - WAP Solo
    - Provides a means of payment to services via WAP for identified ticketing sites
    - Payments either from your bank account or via credit cards - including 3rd parties
  - iMode Felicia
    - Wireless payment scheme
      - Similar to use of Oyster card
      - Used for shopping, transportation, ticketing, membership card, etc
  - SMS payment and alerts
    - Warnings when bank limits are approached or new payments are instructed

- Advantages
  - Shorter queues with lower operating costs
  - Relax need for on-the-spot revenue collection technologies
    - e.g. coin-operated parking meters

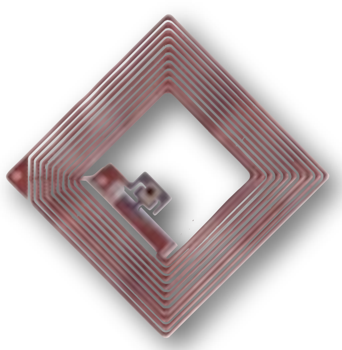
# Mock Questions 2011

- **Question 2**
  - Speculate on how RFID sensors could be used to transform a mobile device into a "self-pay" point-of-sales device? How could a store differentiate between legitimate purchases and shoplifted goods? (5 marks)

**What are the issues?**

# Sensors: RFID

- Radio-frequency Identification (RFID) uses a tag with a unique ID for tagging "things"
  - Three tag types
    - Passive: no battery - coiled antenna induces current which powers the tag and and encoded information is transmitted
    - Active: battery operated - can transmit signals autonomously
    - Battery Assisted Passive: requires external power to wake, but has greater range



  - Used mainly in inventory and supply-chain management
    - Increasing used in:
      - Contact-less Mobile Payment (e.g. Nokia's RFID shells)
      - Location-based services (e.g. in museums)
      - Bar code replacement
    - Can be used as external cues by mobile devices

# Excellent Solution (10/10)

**The Desktop and Mobile E-Commerce experience can differ wildly. Describe one limitation and one advantage of using a mobile device for e-commerce. (5 marks)**

Two of the essential differences between the desktop and mobile E-commerce experiences are that of mobility and screen size. Desktop devices lack mobility, but enjoy the advantage of having large screens which can display a large amount of information graphically, whereas mobile devices lack that screen size, and therefore can only display a small amount of information. In contrast, Mobile devices can be taken into conventional "brick-and-mortar" stores, to assist in the purchasing of goods, whereas the desktop typically only supports commerce from a fixed location.

Given this, a limitation of using a mobile device for e-commerce is the lack of screen space for displaying much of the information typically presented to desktops through e-commerce sites. In many cases, products are not only listed, but can be organised graphically, or compared with other products. Information such as recommendations, related products or reviews can be displayed, as well as other links to browsing, search (via filters on price range, goods, or even manufacturers). Whilst this has greatly enhanced the shopping experience for online purchasers, the lack of screen size on mobile devices undermines the experience on a mobile device. If the user is browsing conventional web sites, the volume of data can often result in pages being rendered very small, requiring the user to zoom in and pan across the screen simply to understand what is being displayed. Some web sites provide mobile-specific web sites, engineered to better facilitate navigation and browsing; however, much of the associated information is often lost, or requires additional work for the user to view it.

In contrast, an advantage of using a mobile device is the ability to use it serendipitously when purchasing goods "on the go". By looking at physical products in shops, it may be possible to then look these up on price-comparison web sites to check out the cost of buying it elsewhere. Many apps now allow users to scan in the bar code, to assist looking up additional details of the product, or to build a virtual shopping list whilst perusing goods in the store, which can then be bought electronically and collected from the store (this is gaining traction with stores that maintain both an online and physical presence).

**Speculate on how RFID sensors could be used to transform a mobile device into a “self-pay” point-of-sales device? How could a store differentiate between legitimate purchases and shoplifted goods? (5 marks)**

RFID (Radio Frequency Identification) is a means of identifying and tracking an RFID tag remotely through the use of an RFID scanner. The range of this tracking can depend on whether or not the RFID tag is powered, but typically, passive tags have a short range and work by becoming powered when passing near a scanner. They can be detected by "exit gates" when a live tag is carried out of a shop, thus creating an alarm; other systems rely on knowing whether a unique tag corresponds to a "purchased" or non-purchased" product.

There is a lot of interest in the integration of RFID scanners into mobile devices that could identify a product and present it as a possible sale item to the user through an application. The user could then choose to buy the item, resulting in a transaction with the store itself, and the resulting receipt being returned to the user. Self Pay systems such as those being introduced by Apple in their stores are based on an approach similar to this. Once the purchase has been made the item corresponding to the RFID tag can be flagged as purchased, thus disarming the security system when the purchaser leaves the shop.

# Poor Solution (6/10)

**The Desktop and Mobile E-Commerce experience can differ wildly. Describe one limitation and one advantage of using a mobile device for e-commerce. (5 marks)**

A limitation of a mobile device is its screen size, as it is difficult to show details of a product being displayed. Also, there is no space to show related information such as recommendations or reviews.

An advantage of a mobile device is that it can be used to support the user when shopping in a store, to find out more information about a product.

**Speculate on how RFID sensors could be used to transform a mobile device into a “self-pay” point-of-sales device? How could a store differentiate between legitimate purchases and shoplifted goods? (5 marks)**

RFID tags could be used to identify a product and therefore allow it to be bought by the device. The receipt could then identify it as being bought, and could be used to deactivate the alarm by the store doors

- Why is this not so good?
  - More detail could be given in each answer - if describing a limitation of one approach in comparison to another approach, describe the difference between the two approaches first.
  - Think the issues through - RFIDs are mentioned, so briefly describe **how** they work, and therefore **why** they could be used in a novel way

# Mock Questions 2011

- **Question 3**
  - Objective-C makes use of reference counting to assist in the management of dynamically allocated memory objects. Discuss how reference counting works through the use of retain and release, and describe how these methods can result in memory being returned to the heap. (4 marks)
  - As a rule of thumb, a developer should never make use of the dealloc method. What is the one exception to this rule, and why? (2 marks)
  - It is often desirable for a method to dynamically allocate memory for a new object from the heap, but then return that object to the calling method (see the incomplete example code fragment below). Describe the problems associated with this, and explain how this could be overcome. (4 marks)

```
- (NSString *) getScoreStr {
    NSNumber *score = [[NSNumber alloc] initWithInt:4];
    NSString *rStr = [[NSString alloc]
                           initWithFormat:@"Score: %@", score];
    [score release];
    return rStr;
}
```

# Mock Questions 2011

- **Question 3**
    - Objective-C makes use of reference counting to assist in the management of dynamically allocated memory objects. Discuss how reference counting works through the use of retain and release, and describe how these methods can result in memory being returned to the heap. (4 marks)

**What are the issues?**

# Reference Counting

- Every object has a retain count
  - Defined on **NSObject** (in the Foundation Framework)
  - As long as retain count is > 0, object is alive and valid
- **`+alloc`** and **`-copy`** create objects with retain count == 1
- **`-retain`** increments retain count
- **`-release`** decrements retain count
- When retain count reaches 0, object is destroyed
  - **`-dealloc`** method invoked automatically
  - Once you're in **`-dealloc`** there's no turning back

# Reference Counting in Action

```
person = [[Person alloc] init];
```

Retain count begins at 1 with **+alloc**

```
[person retain];
```

Retain count increases to 2 with **-retain**

```
printf("The reference count is %i\n", [fraction retainCount]);
```

The reference count will be returned as an integer

```
[person release];
```

Retain count decreases to 1 with **-release**

```
[person release];
```

Retain count decreases to 0: **-dealloc** automatically called

# Mock Questions 2011

- **Question 3**
  - As a rule of thumb, a developer should never make use of the dealloc method. What is the one exception to this rule, and why? (2 marks)

**What are the issues?**

# Object Lifecycle Recap

- Objects begin with a retain count of 1
  - Increase with -retain
  - Decrease with -release
- When the retain count reaches 0, the object is deallocated automatically
- You **never** need to call dealloc explicitly in your code
  - The only exception is when redefining the dealloc method to do additional housekeeping
    - In this case, send a message to the superclass via [super dealloc]
- You only deal with `alloc`, `copy`, `retain`, and `release`

# Mock Questions 2011

- **Question 3**
  - It is often desirable for a method to dynamically allocate memory for a new object from the heap, but then return that object to the calling method (see the incomplete example code fragment below). Describe the problems associated with this, and explain how this could be overcome. (4 marks)

```
- (NSString *) getScoreStr {
    NSNumber *score = [[NSNumber alloc] initWithInt:4];
    NSString *rStr = [[NSString alloc]
                         initWithFormat:@"Score: %@", score];
    [score release];
    return rStr;
}
```

**What are the issues?**

# Returning a newly created object

- In some cases, objects may be passed with no clear or obvious ownership
  - Hence no responsibility to clean up

```
- (NSString *)fullName {
    NSString *result;
    result = [[NSString alloc] initWithFormat:@“%@ %@”,
                               firstName, lastName];
    return result;

    // result was allocated from the heap...
    // ... but now it has been passed to the calling
    // method, it is too late for fullName to manage it!
}
```

- In this case, result is leaked...!
  - result is passed as an allocated object with no owner

# Returning a newly created object

- Can't release result before it is returned
  - Yet, after `return`, the method looses access to the object

```
- (NSString *)fullName {
    NSString *result;
    result = [[NSString alloc] initWithFormat:@"%@ %@",
                               firstName, lastName];
    [result autorelease];
    return result;

    // result was allocated from the heap...
    // ... and is now managed by autorelease :)
}
```

- result will be released some time in the future (not now)
  - caller can choose to `retain` it to keep it around!

# How does -autorelease work???

1. Object is added to current autorelease pool

2. Autorelease pools track objects scheduled to be released
   - When the pool itself is released, it in turn sends the -release message to all its objects

3. UIKit automatically wraps a pool around every event dispatch
   - Important for event driven GUI programming
     - See later...!

# Excellent Solution (10/10)

**Objective-C makes use of reference counting to assist in the management of dynamically allocated memory objects. Discuss how reference counting works through the use of retain and release, and describe how these methods can result in memory being returned to the heap. (4 marks)**

One of the main challenges of memory management in Objective C is that of dynamically allocating memory for objects, and then freeing up that memory once it is no longer needed. In addition, objects may themselves be owned by more than one variable or other object, making it difficult to keep track of when they are no longer needed. As such, Reference Counting is used with dynamically allocated memory objects. When an object is first created, it has an associated retain count, which is set to 1. The retain method can then be called to increment this count, and correspondingly, the release method can be used to decrement the count. Therefore, if a second variable wants to share the object, it can increment the count by calling retain, and once it no longer needs the object, it can call release. Once the retain count falls to zero (i.e. the last variable releases the object), then the object is automatically deallocated, and the object is returned to the heap.

**As a rule of thumb, a developer should never make use of the dealloc method. What is the one exception to this rule, and why? (2 marks)**

Because of the reference counting method, the dealloc method, which results in the object's memory being returned to the heap, should never be called. The only exception is when defining a dealloc method for a class, when it is important that any memory exclusively managed by that class is also freed. In which case: 1) you override the parents dealloc method; 2) you call the parent's dealloc method; and 3) you call dealloc on any objects that are part of the class, and need to be cleaned up.

**It is often desirable for a method to dynamically allocate memory for a new object from the heap, but then return that object to the calling method (see the incomplete example code fragment below). Describe the problems associated with this, and explain how this could be overcome. (4 marks)**

Sometimes memory is allocated in a class to create an object which will subsequently be returned to the caller. However, ownership of the object is then an issue - the method creating the object cannot release the memory itself, as that would destroy the object before it is used. Yet, it cannot be sure that the caller will take responsibility for releasing the object created by the method, as it is not always desirable that the caller should release that object (e.g. this would not be desirable in a getter method of a retained property).

Autorelease is a mechanism that can be used to temporarily retain objects. GUI based applications use an event-based processing model: when an event occurs (such as the user interacting with the app, or an external action such as new data or a timer triggers an event), the code associated with that event is executed. Once all the code for that event has finished executing, the next event is processed. An autorelease pool is created when an event is about to be processed, and released once the event has been processed. When the autorelease method is called on an object, its ownership is passed to the autorelease pool, leaving the pool responsible for releasing the object. As objects in this pool will not be released until the code for an event has been processed, this means that objects that have been autoreleased are valid until the event has been processed, which is typically long enough for then to be passed between methods. If the object should be kept beyond the event processing, it can be retained, and the ownership passed to another object.

# Poor Solution (5/10)

**Objective-C makes use of reference counting to assist in the management of dynamically allocated memory objects. Discuss how reference counting works through the use of retain and release, and describe how these methods can result in memory being returned to the heap. (4 marks)**

Reference counting keeps a count of the number of variables using the object. When another variable wants to share the object, it calls retain. When it is then finished with the object, it calls release. When all the variables have released the object, it is returned to the heap.

**As a rule of thumb, a developer should never make use of the dealloc method. What is the one exception to this rule, and why? (2 marks)**

Dealloc can be defined within a class when the object is being destroyed, as the memory for this is no longer required for that object.

**It is often desirable for a method to dynamically allocate memory for a new object from the heap, but then return that object to the calling method (see the incomplete example code fragment below). Describe the problems associated with this, and explain how this could be overcome. (4 marks)**

The problem is that as the method has to return rStr, it can't release it. Autorelease can be used instead as it temporarily retains objects until the autorelease pool is released.

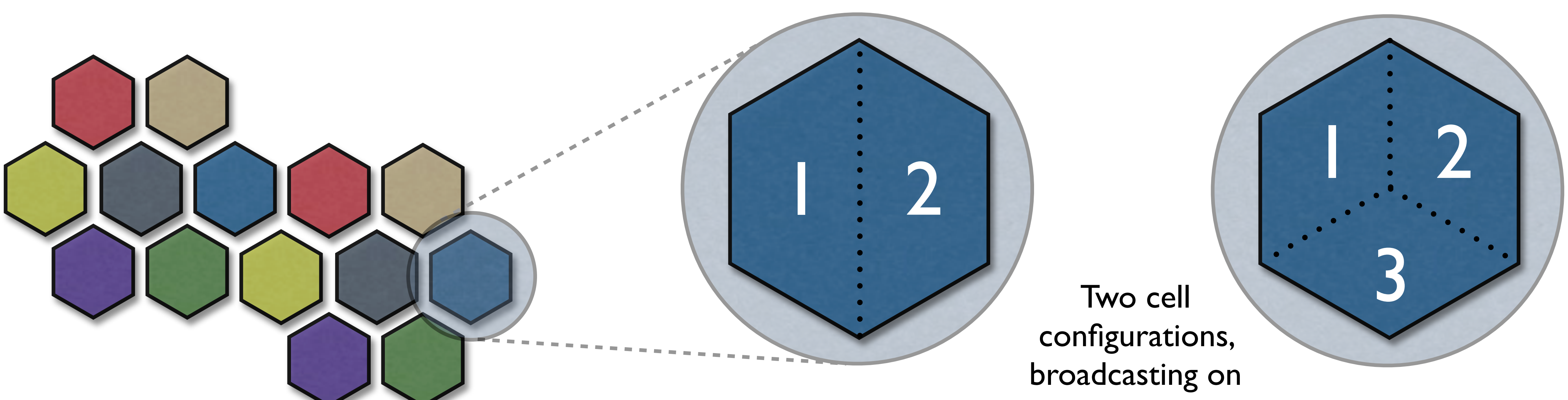
- Why is this not so good?
  - It is lacking in detail, and in justification.

# Mock Questions 2011

- **Question 4**
  - Assume a GSM Base Transceiver Station cell is split into 3 sectors, with each sector covered with 2 transmitter/receiver pairs. Also assume that each transmitter/receiver pair uses 1 time slot for signalling, and an additional time slot for GPRS data. Given a theoretical call profile model of 2 minutes per hour, what would be the subscriber provision for that cell? (6 marks)
  - If the demand for data increases the number of time slots needed for GPRS data from 1 to 3 time slots per transmitter/receiver pair, how many additional transmitter/receiver pairs will be needed per sector to maintain the same subscriber provision for that cell? (4 marks)

# GSM BTS Cells

- A form of space division multiplexing is used to avoid interference
  - Each cell typically only operates on a limited number of frequencies, to avoid interference with its neighbours
  - To increase capacity, the coverage area is usually split into two or three sectors, covered using different frequencies by a dedicated transmitter
    - Improves reuse of frequencies in 2D space, compared to a single frequency per cell.




Two cell configurations, broadcasting on different frequencies

# Cell Capacity

- It is possible to calculate the cell capacity, and hence estimate subscriber provision
- Example scenario
    - Assume a BTS cell is split into 3 sectors, with each sector covered by 2 transmitters and 2 receivers.
    - Also assume that each transmitter/receiver pair uses 1 time slot for signalling, and 2 time slots for GPRS data
- Each GSM channel consists of 8 time slots, with uplink data going to the receiver, and downlink data coming from the transmitter
    - Therefore each transmitter/receiver pair has 5 time slots for voice calls
    - Given that there are two transmitter/receiver pairs in each sector, with three sectors in the cell, **the cell capacity is (5x2x3 =) 30 simultaneous subscribers.**
- Not all subscribers communicate at the same time.
    - Mobile providers use a "*theoretical call profile model*" to determine the number of minutes on average a subscriber uses per hour.
    - If this profile states that for an hour, the average use is 1 min, then a cell can support 60 times the number of active subscribers.
    - **Hence, the subscriber provision per cell is (30x60 = ) 1800 subscribers.**

**Case Study**

Vodafone Germany had a subscriber base of aprox 25 million in 2005. By dividing this number by the subscriber provision per cell, the number of BTSs needed can be calculated.

Given the figures opposite, this would be aprox 14,000, which is in line with the number of actual BTs used by Vodafone Germany!!!

# Excellent Solution (10/10)

**Assume a GSM Base Transceiver Station cell is split into 3 sectors, with each sector covered with 2 transmitter/receiver pairs. Also assume that each transmitter/receiver pair uses 1 time slot for signalling, and an additional time slot for GPRS data. Given a theoretical call profile model of 2 minutes per hour, what would be the subscriber provision for that cell? (6 marks)**

A GSM frame consists of 8 time slots that can be used for signalling, voice circuits and GPRS data packets. Therefore, each transmitter/receiver pair can support six time slots for voice calls. Given that there are two transmitter/receiver pairs in each sector, with three sectors in the cell, the cell capacity is v x s x t, where v is the number of voice time slots, s is the number of sectors, and t is the number of transceivers (i.e. transmitter/receiver pairs).

This gives: 6 x 3 x 2 = 36 simultaneous subscribers.

The theoretical call profile model determines the actual subscriber provision, given the number of possible simultaneous subscribers. As this profile assumes (on average) 2 minutes of use per subscriber per hour (i.e. a provision of 30 subscribers per hour), the subscriber provision per cell would be 30 x 36 = 1080 subscribers.

**If the demand for data increases the number of time slots needed for GPRS data from 1 to 3 time slots per transmitter/receiver pair, how many additional transmitter/receiver pairs will be needed per sector to maintain the same subscriber provision for that cell? (4 marks)**

If the data demand increases from one time slot to three, this will reduce the number of time slots available for calls from 6 to 4 time slots. To maintain the same provision per cell (given that the theoretical call profile model doesn't change), the number of transmitter/receiver pairs would have to increase to maintain a capacity of 36 simultaneous subscribers.

Thus, we have to calculate 4 x 3 x t = 36, where t is the number of transceivers required to maintain a capacity of 36 simultaneous subscribers. Therefore, t=3, resulting in the need of one additional transmitter/receiver pair necessary per sector.

# Poor Solution (5/10)

**Assume a GSM Base Transceiver Station cell is split into 3 sectors, with each sector covered with 2 transmitter/receiver pairs. Also assume that each transmitter/receiver pair uses 1 time slot for signalling, and an additional time slot for GPRS data. Given a theoretical call profile model of 2 minutes per hour, what would be the subscriber provision for that cell? (6 marks)**

6 time slots for each transmitter/receiver pair
6 transmitter pairs in a cell
36 simultaneous calls
30 calls per hour
1080 subscribers

**If the demand for data increases the number of time slots needed for GPRS data from 1 to 3 time slots per transmitter/receiver pair, how many additional transmitter/receiver pairs will be needed per sector to maintain the same subscriber provision for that cell? (4 marks)**

Maintain 36 simultaneous calls
Now only 4 time slots for each transmitter/receiver pair
Three sectors, so 12 calls per sector
Need 3 transmitter/receiver pairs

- Why is this not so good?
  - No explanation as to the working method, or explanation as to where or how the figures were obtained