**1.  
What are the typical components of a node? Sensor**

* 1. **Controller:**Responsible for processing relevant data and executing arbitrary code.
  2. **Watchdog:**Manages sensor-controlled, time-controlled, or communication-controlled wake-up mechanisms.
  3. **Wireless Radio:**Provides short-range communication with low bitrate using CMOS radios (1-10 mW).
  4. **Sensors:**Devices like thermometers, cameras, motion detectors, and light sensors that collect data from the environment.
  5. **Power Supply:**Can be batteries (1,000 mWh/cm³), solar power (10 mW/cm², 0.1 mW indoors), or vibration energy (~µW/gm).  
     These components work together to ensure the sensor node can collect, process, and transmit data efficiently while being energy-conscious.

**2.  
Which component of a sensor node has a major influence on its autonomous lifetime?  
Wireless Radio**: Data exchange requires a significant amount of energy. Reducing data transmission can greatly enhance the node's lifetime.   
**Power Supply**: A larger power supply, such as higher capacity batteries or more efficient energy harvesting methods (solar, vibration), directly increases operation time.

* 1. **Are there any other components that have a major influence on its autonomous lifetime?**  
       
     **Controller**: The energy consumption of the microcontroller varies based on its type and the operations it performs.   
       
     **Sensors:** The type and number of sensors used, and their operational power requirements, also affect the node's energy consumption. Some sensors might require more frequent data sampling or more power to operate.   
       
     **Watchdog:** While typically low-power, the energy efficiency of the watchdog timer in managing wake-up cycles can impact overall power consumption.  
       
     **3.**

**What are the key differences between a wireless ad-hoc network and a conventional wired network?**  
Wireless Ad-hoc relies on wireless communication without pre-existing infrastructure such as a router or an access point, whereas for wired connection we use cables or wires for communication, relying on a fixed structure with routers or switches.   
The topology in wireless networks is considered to be decentralized and dynamic, which means basically each node can act as both a router and an end device, where as in wired networks the topology is centralized and static, with fixed pathways for data transmissions.   
  
Wired networks are more reliable due to stable and high-bandwidth connections, whereas wireless networks are less reliable due to the mobility of the nodes which can interrupt the connection.   
  
Moreover, Wireless Ad-Hoc network is divided in to types:

**Infrastructure-Based Networks (IBCN)**These networks rely on pre-existing infrastructure such as routers, access points, and base stations to manage communication and network operations

**Mobile Ad-Hoc Network(M-AdHoc Networks)**  
These networks do not rely on any pre-existing infrastructure. Instead, nodes communicate directly with each other and dynamically configure the network as nodes move, join, or leave. On to the same topic of wireless networks, there are protocols such as multihop communication that helps the wireless communication to extend the effective range by relying on the intermediate nodes where at the same time energy consumption is

**4.  
How does the power of a radio signal at the location of a transmitter relate to the power of the radio signal at the location of the receiver?**The power of a radio signal at the location of a transmitter relates to the power of the radio signal at the location of the receiver through a concept called path loss or attenuation. Path loss represents the reduction in power density of an electromagnetic wave as it propagates through spaceThe power must be equal to the number of hop times the distance to each device consideration of the signal attenuation  
  
**5.**

**Outline why multi-hop wireless communication is more energy- efficient than single -hop wireless communication**Multiple-hop wireless communication is more energy-efficient than the single-hop wireless communication due to the way the signal strength varies with distance. In Single hop communication, the signal needs to cover a longer distance directly from the transmitter to the receiver, the power required for this transmission increases significantly with distance due to the path loss exponent which typically ranges  
  
The reason multi-hop communication is overall more energy-efficient is because it divides the distance into smaller segments. Each hop covers a short distance requiring significantly less transmission power for each individual hop. The denser the nodes are in the network the more energy efficient it gets.  
  
**6.**

**What is meant by the term “Data centricity” in relation to sensor networks**Data Centricity in relation to sensor networks refers to the focus on data itself rather than on which individual sensor is generating the data. This approach prioritizes the information being collected, processed and queried over the specifics of which sensor nodes are providing the data.   
The following are desired properties for wireless data networks.

**User Interest in Data:**  
Users are more interested in the data being generated, such as specific events or measurements, breathe than the identity or location of the sensor nodes

**Decoupling in Space and Time**:  
Decoupling in space means neither the sender nor the recovery needs to know each other's specific identity or location. Moreover, decoupling in time means the communication can be asynchronous. An answer to a data query does not need to be directly and immediately triggered by the question. This allows for more flexible and resilient data handling. By using the concept of Publish/Subscribe Paradigm, we can safely that in Wireless Sensor Networks, which is the publish/subscribe model, follows the concept of Data Centricity, as the following observations can be evaluated:

Publish/Subscribe Paradigm:  
**Publishers**: Nodes that generate and send data.

**Subscribers**: Nodes or entities that express interest in specific types of data.

**Software Bus**: Manages subscriptions and directs relevant data from publishers to subscribers.

Finally, this means the publishers and subscribers do not need to know each other's identity or location, and communication can be asynchronous, this refers to decoupling in space and time. Subscriptions are filtered by content, and updates are sent only to the interested parties, optimizing the networks.

**7.  
What is the typical networking interaction paradigm in wireless sensor networks? Describe this concept!**The typical networking interaction paradigm in wireless sensor networks is the publish/subscribe paradigm.  In this model, publishers send data to a central software bus, which stores subscriptions from various subscribers. When the data changes, the software bus notifies the relevant subscribers based on their subscriptions, enabling efficient and decoupled communication between publishers and subscribers.  
A diagram of software bus

Description automatically generated

**8.  
What is meant by the term “Partial State Record”**A partial state record refers to the intermediate result of the aggregation process in a wireless sensor network. These records are crucial for efficiently computing aggregated values like average, sums, or other statistical measures across distributed sensor nodes.  
Purpose is to basically store intermediate results of aggregation operations as data is collected and processed by sensor nodes. Another good thing is that they are efficient, they enable the computation of the final aggregated values without requiring all raw data to be transmitted to a central location, thereby saving energy and bandwidth.  
Types of Partial State Record are distributive, algebraic, holistic or content sensitive, for example distributive and algebraic partial states are well-suited for in network aggregation because they can be efficiently computed and combined, whereas, holistic and content-sensitive aggregate functions may not be as practical for in network aggregation due to their complexity and the amount of data they many require

**9.  
Which are typical properties of aggregation function in relation to the unreliable character of wireless communication.**Aggregation functions are used in wireless sensor networks to compute summary data from multiple sensor nodes that are then stored in the Partial State Records. Given the unreliable nature of wireless communication, certain properties of these functions are particularly important so that we are able to provide accurate and reliable data values in challenging wireless communication environments, for example: **Duplicate Sensitive Aggregates:**So due to unreliable connection if there are duplicate values, while using the SUM or AVERAGE function, the repeated values are considered as once  
  
**Exemplary Aggregates**  
So due to unreliable connection, functions like MIN or MAX focus on returning a single, representative value from the dataset  
  
  
**10.**

**Why is the sequential programming model unsuitable for programming sensor node?** In the case of sequential programming model, the sensor is being polled for available data**.** Also, the transceiver is being polled for any packets arrived or packets that must be transmitted. There are couple of risks with this programming model.  
 1. We can miss some data from the sensors while a packet is received or processed  
 2. We can miss a packet when the sensor information is being processed  
  
 A diagram of a process flow

Description automatically generated

**11.  
Why is the process-based programming model unsuitable for programming sensor nodes?** In case of process-based programming model, we have two separate processes or threads;  
 1. One for handling sensors.  
 2. Second is for the packets  
This produces too much overhead because the following reasons:  
 1. A lot of memory is required, since each process requires its own stack space  
 in the memory  
 2. The context switch between the processes has a high rate.  
 A diagram of a process

Description automatically generated

**12.  
Which programming model is suitable for sensors? Describe this programming paradigm!**The programming model suitable for sensor nodes is the **event-based programming**, the reason, in this case, a sensor node waits for any event to happen.   
  
This can be, for example, a timeout event, **available data from a sensor**, **or an arrival of a packet.**  
Once the event has occurred, it is then handled by a short sequence of instructions.  
  
 **Some Deep explanation**:  
 How it works  
            1. **Types of Events**:  
                         Timeout Events: Triggered after a specified time interval  
                         Sensor data availability: New data from a sensor becomes available  
                          Packet arrival: A data packet arrives from another node  
            2. **Event Handling**:       
 i.When an event occurs, the sensor node transitions from idle or regular  
                            processing to an event-specific handler  
                        ii. **Sensor Event Handler**: Activated when a sensor-related event      
                            occurs such as new data availability.  
            iii. **Radio Event Handler**: Activated when a communication-related event  
                          occurs, like the arrival of a data packet.  
            3. **Instruction Execution**:          
 i.  Upon activation by an event, the node executes a short sequence of  
                             instructions tailored to handle that specific event

**13.  
TinyOS applications are written in nesC. nesC uses two types of components. What functions do “ modules" have, and what functions do  “Configurations” have in a nesC application?** The nesC implementation consists of two parts:  
            A PowerupC modul and a PowerupApp C configuration  
            The module PowerupC contains the executable logic of the application  
 The module resides in the file Powerup.nc  
    
  
            **Modul Powerup C**{  
                          uses interface Boot;  
                          uses interface Leds;  
                                         }  
            **implementation**{  
            event void Boot.booted(){  
                          call Leds.led0On();  
                            }  
                        }  
  
            **Configuration** PowerupAppC   
            }  
            **implementation**{  
                      components MainC, LedsC, PowerupC;  
                          PowerupC.Boot -> MainC.Boot;  
                          PowerupC.Leds -> LedsC.Leds;  
            }

It is advised to explain the code, for yeah passing the exam  
 Writing the code in the exam would give us points or?

**14.  
What does the term “wiring” mean in relation to nesC application?** The term “wiring” means binding an interface user to an interface provider. In other words, configuration consists of a signature and an implementation block. The implementation block can bind an interface user to a provider using  
            the -> or <- operator  
            This process is called wiring  
  
 Example is given in question 13

**15.  
The functional relationship between different nesC components is defined by interfaces. Which functions are implemented by interface providers and which functions are implemented by interface users?**In nesC programming, the functional relationship between components is defined by interfaces, where interface users and providers have distinct roles. Interface users can call commands provided by the interface and must implement the events signaled by the providers. On the other hand, interface providers are responsible for implementing the commands that users can call and can signal events that the users must handle.  
  
This clear division of responsibilities ensures structured and modular interaction between different components in nesC, enhancing the overall functionality and maintainability of the system.  
  
**16.**

**Many TinyOS interface are “Split phase”. What does this term mean?** This means that the user of the interface sends a command  
 The provider of the interface performs the associated operation  
 The provider signals an event that indicates the completion of the operations  
 A diagram of a software application

Description automatically generated

**17.  
The execution model of TinyOS uses “tasks”. Which special functions do these tasks have?**Tasks are very particular functions; they are an important building block for the execution model. Tasks look like C functions, but:  
            1. They can’t have a return value  
            2. They don’t take any parameters  
            3. They can be executed only within the naming scope of a component  
 4. Tasks schedule a function to be called later  
            5. Taks do not interrupt one another  
            6. Tasks can be seen as time-flexible background jobs

**Describe the execution model implemented by TinyOS! How does Tiny OS’s scheduler work?**          1. Split-Phase Interface  
                         Operations like sending packets or sampling sensor are handled in two  
                          phases:  
                                         1. Command initiation: A non-blocking command starts the  
                                         operations and immediately returns.  
                                         2. Interrupt Handling: The hardware component issues an  
                                         interrupt when the operations is complete  
                                         3. An event handler processes the completion and can post a  
                                         new tasks  
            2. Execution Model  
 1. Energy saving:   
 The mote stays asleep most of the time to energy  
                                    2. Computation Start: Computation is initiated by the hardware   
                                         interrupts.   
 (The post operations adds tasks to an internal task  
                                         queue)  
            3. Scheduler Operations:  
                                   1. Tasks Queue Processing:   
 The scheduler processes tasks in  
                                         First In, First Out (FIFO)  
                                   Interrupts can interrupt tasks and post additional tasks

**Chapter 3  
  
Personal**

A screenshot of a computer

Description automatically generated

1. **What are the characteristics of the “request-response” communication model?**Its a stateless communication model. Each request-response pair is independent of each other   
   A diagram of a server

   Description automatically generated  
   Clients sends a request to a sever, and the server responds to the request, now when the server receive the request, it decided how to respond fetches the required data from the database, prepares the response in an appropriate represents like in JSON and sends the response to the client. As this a stateless mode of communication so, so all the requests are independent to each other  
     
   Example: HTTP
2. **What are the characteristics of the “publish-subscribe” communication model**A diagram of a subscriber

   Description automatically generated

The Publish-Subscribe communication model involves three main instances: **publishers, consumers, and brokers**, it is suitable in event driven applications  
Publishers act as sources of data, sending messages to specific sever called the broker, the broker handles the routing distributions of the message, to the various subscribers/consumers.   
Consumers subscribe to these topics to receive relevant data.   
Brokers manage the topics and facilitate the forwarding of messages from publishers to the appropriate consumers.   
This model decouples the producers and consumers of data, enhancing scalability and flexibility. For example, a publisher can send messages to topics such as Topic 1 and Topic 2, and brokers ensure these messages are delivered to all consumers subscribed to those topics, allowing Consumer 1, Consumer 2, and Consumer 3 to receive only the data they are interested in.  
  
Example MQTT

1. **What are the characteristics of the “push-pull” communication model?**A diagram of a company

   Description automatically generatedThe "Push-Pull" communication model uses queues to decouple messaging between producers and consumers. Producers send messages to queues, which act as buffers to handle inconsistent data rates between producers and consumers. This decoupling allows producers and consumers to operate independently, with queues managing the flow of messages to ensure consumers can process them at their own pace. This model enhances flexibility and scalability, as it allows the system to handle varying speeds of message production and consumption effectively.  
     
   This is many used to have consistency with data rate between Publisher and Consumers
2. **What are the characteristics of the “exclusive pair” communication model?**A diagram of communication

   Description automatically generatedThe "Exclusive Pair" communication model is a bi-directional including full duplex concept between in the network and is a stateful communication method that maintains a persistent connection between a client and a server. This model allows both the client and server to continuously exchange messages over the same connection until it is explicitly closed. It begins with the client requesting to set up the connection, followed by the server's response accepting it. Messages are then sent back and forth, and the connection is closed upon request and confirmation from both sides. This approach ensures efficient and continuous communication without the need to repeatedly establish new connections.  
     
   **Example; Web Socket Based Communication API**
3. **What is the purpose of the 6LoWPAN network layer protocol?**The purpose of the 6LoWPAN network layer protocol is to enable IPv6 to be used with wireless embedded devices. Since Zigbee does not natively support Internet protocols, 6LoWPAN allows these devices to communicate using the standard Internet Protocol, thereby facilitating the integration of wireless embedded devices into IP-based networks.   
     
   Here are some key features and function that this network layer protocol provides
   1. **Enables IPv6 for low devices:** as low power wireless networks like using IEEE 802.15.4 (Zigbee), this doesn’t typically support the full suite of Internet protocols, that’s why using 6LoWPAN network layer protocol provides a framework that allows IPv6 packets to be sent and received over IEEE 802.15.4 based networks.
   2. **Efficient Packet Transmission:** The challenge is that IPv6 headers are large, which can be too big for the small frame sizes of IEE 802.15.4 networks, that’s why using 6L0WPAN includes header compression techniques that significantly reduces the size of IPv6 packets. For example, it can compress the IPv6 header and UDP header to just **7 bytes**, making them suitable for transmission over low-power wireless networkit also supports the mesh networking, this is realized by intermediate Edge routers which connect the wireless network with the wired IP version 6 network.
4. **How does the network protocol COAP work in principle?**COAP is a stateless request/response machine to machine protocol. However, a separate protocol extension is used to allow observation of resources. Like in the case of MQTT, a client can subscribe to a resource. It is built on top of UDP (User Datagram Protocol) instead of TCP, which helps in reducing overhead and maintaining efficiency. CoAP supports the standard HTTP methods (GET, POST, PUT, DELETE) for resource manipulation.
5. **How does the network protocol MQTT work in principle**MQTT works on the publish-subscribe communication model where a client connects to a broker, which acknowledges the connection and keeps it alive as long as possible. The client subscribes to specific topics on the broker, and the broker manages message distribution to all subscribed clients. The MQTT protocol allows clients to send regular ping requests to maintain the connection and uses "last will and testament" messages to notify others when a client disconnects. Implemented via TLS for security, MQTT brokers can request authentication details like username and password. This model negates the need for constant polling, enhancing efficiency.  
     
   **Quality of Service Levels**: MQTT supports three levels of Quality of Service (QoS), which are crucial for ensuring message delivery based on the needs of specific applications:

- \*QoS 0\*: The message is delivered at most once, without guarantee.

- \*QoS 1\*: The message is delivered at least once.

- \*QoS 2\*: The message is delivered exactly once, ensuring that each message is received only once by the subscribers**.**

1. **What role do "topics" have in the MQTT protocol?**MQTT topics are very lightweight. A topic is a UTF-8 string, which is used by the broker to filter messages. Subscribers are often interested in a great number of topics, Individual subscribing to each topic would be cumbersome (Wild cards).   
     
   An example of how a topic looks in this context:  
   myhome/groundfloor/livingroom/temperature
2. **What role do the symbols "\*" and "#" have in relation to MQTT topics?**In MQTT topics, the symbols "+" and "#" serve as wildcards to simplify subscription to multiple topic levels. The "+" symbol is a single-level wildcard that matches one topic level. For example, "building/+/sensors" can match "building/floor-1/sensors" and "building/floor-2/sensors". The "#" symbol is a multi-level wildcard that matches multiple topic levels, such as "building/floor-1/#", which can match all sub-topics under "building/floor-1", like "building/floor-1/sensors" and "building/floor-1/blinds". These wildcards make it easier to subscribe to a broad range of topics without specifying each one individually.  
     
   A screenshot of a computer

   Description automatically generated
3. **What advantages and disadvantages does MQTT have over COAP?**  Advantages:
   1. MQTT has a highly decoupled publisher and subscriber model, whereas CoAP has an asynchronous communication model.
   2. MQTT allows 16 different types of messages, whereas, CoAP allows only 4 types.
   3. MQTT offers three levels of Quality of Service (QoS) for message delivery (at most once, at least once, exactly once), ensuring reliable communication as per application requirements.   
        
      Disadvantages:
   4. MQTT uses TCP connections, which require keeping the connection alive for longer periods. This increases power consumption, making it less suitable for battery-operated IoT devices compared to CoAP, which uses the more lightweight UDP.
   5. MQTT packets are generally larger than CoAP packets, which can lead to higher overhead and reduced efficiency
4. **Which architectural principles are implemented by REST-based APIs?**   
   REST-based APIs implement key architectural principles including **uniform interfaces** for consistent resource access, **stateless** communication where each request contains all necessary information, and **cacheable** to enhance efficiency by allowing response caching. The **client-server model** separates the user interface from data storage and processing, enabling independent development and scalability. These principles collectively ensure simplicity, scalability, and performance in web services.
5. **What special features does the WebSocket communication protocol have?**
   1. **Allow bi-directional, full-duplex communication between clients and servers over the TCP connection** 
      1. Exclusive pair communication model
   2. **Does not require a new communication setup for each message to be sent**
      1. Unlike response/request APIs such as REST
   3. **Suitable for applications with low latency / high throughput requirements**
      1. No overhead for connection setup
      2. There is no HTTP header information included in each message  
         A white background with black text

         Description automatically generated
6. **Are there IoT use cases where a WebSocket-based API is better suited than a REST-based API? Describe an example!**  
   OLD  
   Yes, a Shipment Monitoring IoT system is a great example of a use case, where a  
   WebSocket-based API is more suitable, since in this case we need a bidirectional persistent connection between the client and the servers.  
     
   NEW  
   Yes, there are IoT use cases where a WebSocket-based API is better suited than a REST-based API. For example, a Shipment Monitoring IoT system benefits significantly from a WebSocket-based API because it requires a bidirectional, persistent connection between clients and servers. This system needs real-time updates on conditions like temperature, humidity, and location of the shipment, which can be efficiently handled by WebSockets. Unlike REST, which involves overhead for each request-response cycle, WebSockets maintain an open connection, allowing for low-latency, high-throughput communication without the need for constant reconnection, making it ideal for continuous monitoring and immediate alerts in shipment tracking.
7. **What functions does the ThingSpeak platform provide for IoT applications?**  
     
   Real-time data collection and analysis
   1. Visualizing the collected data in the form of charts
   2. Ability to create apps for collaborating with web services
8. **Django´s core structure can be broken into three parts: Models, Views and Templates. Describe the function of these three components!**   
    **NEW**  
   Models.  
   Models serve as the data layer in Django. They define the structure of the data in the database by representing what the objects in the database will look like. For  
   example:  
   **from django.db import models**  
   **class Student**(models.Model):  
    first\_name = models.CharField(max\_length=30)  
    last\_name = models.CharField(max\_length=30)  
    age = models.IntegerField()
   1. In this example,
      1. **First\_name, last\_name, and age** are fields in each Student object.
      2. **Django provides easy-to-use validation** methods such as CharField, IntegerField, and others, allowing model fields to accept only certain types of inputs
   2. Templates:   
      A template is an HTML page used to present data. It includes:
      1. The static parts of the desired HTML output.
      2. Special syntax for inserting dynamic content.
   3. Views:   
      Views act as the bridge between models and templates. They:
      1. Tie the model to the template.
      2. Contain the logic that generates the web pages.
      3. Determine what data to display.
      4. Retrieve data from the database.
      5. Pass the data to the template for rendering.

Chapter 4

1. **What is the difference between coarse-grained and fine-grained localization techniques?**  
   Coarse-grained localization techniques use minimal information to estimate a node's location, relying on methods such as proximity detection, centroid calculation, and APIT (Approximate Point-In-Triangle), which involve basic positional estimates based on limited data. In contrast, fine-grained localization techniques provide more precise and detailed location information by using advanced methods like Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), and Received Signal Strength (RSS), which measure exact distances and angles to achieve higher accuracy in determining a node's position, they don’t require additional hardware.
2. **How does the Centroid Algorithm work to locate sensor nodes?**  
   The Centroid Algorithm is based on Coarse-grained technique, locates sensor   
   nodes in a 2-dimensional sensor network by utilizing beacons with known positions that periodically broadcast their exact coordinates. Sensor nodes collect these broadcasts over a set time interval.   
   At the end of this period, each sensor node calculates its position as the average of all received beacon coordinates, effectively finding its approximate location based on the centroid of the beacons' positions it has detected. This method assumes a finite network with a specific number of sensor nodes and beacons.  
     
   Explain the formula  
   A close-up of a white rectangular object

   Description automatically generatedBased on the known position of the anchor nodes, more anchor nodes mean better precision
3. **Which parameters determine the localization accuracy of the Centroid Algorithm?**

The localization accuracy of the Centroid Algorithm is primarily determined by the transmission range \( r \) and the separation distance \( d \). The error in location is influenced by the overlap ratio \( r/d \), with better accuracy achieved when the transmission range covers more area relative to the distance between beacons.

1. **How can the reliability of the Centroid Algorithm be increased in practice?**The reliability of the Centroid Algorithm can be increased by adding more sensor nodes. This enhances the network density, providing more data points for averaging, which in turn improves the accuracy of the localization.
2. **Describe the basic idea of the APIT localization method?**The APIT (**Approximate Point-In-Triangle**) localization method involves determining the triangles formed by any three anchor nodes in which a sensor node is located. By overlapping these triangles, the algorithm refines the estimated position of the sensor node, effectively narrowing down its possible location area through multiple triangular regions.^
3. **How to decide whether a node is inside or outside a triangle?**if a node is inside triangle ΔABC, when the node is shifted in any direction, its new position must be nearer to (further from) at least one anchor A, B or C. If a node is outside triangle ΔABC, when the node is shifted, there must exist a direction in which its position is further from or closer to all three anchors A, B and C.
4. **Describe the 4 steps of the APIT method for locating a sensor node. (Verify the steps from the Prof.)**

**Step 1: Formation of Triangles**

Anchor Nodes Identification:

• Identify and utilize anchor nodes (nodes with known positions) within the network.

• For a given sensor node, determine all possible triangles that can be formed using any three anchor nodes.

**Step 2: Inside-Outside Test**

**Point-in-Triangle Test:**

• For each triangle formed in Step 1, perform a test to determine whether the sensor node is inside or outside the triangle.

• This test involves checking if the node's position changes relative to the anchor nodes when the node is shifted in various directions.

• Inside Triangle: If shifting the node in any direction makes it closer to at least one anchor node, it is inside the triangle.

• Outside Triangle: If there is a direction where shifting the node makes it further from or closer to all three anchor nodes simultaneously, it is outside the triangle.

**Step 3: Neighbor Distance Inquiry**

Distance Comparisons:

•Instead of physically moving the sensor node, which is impractical, the node queries its neighbors about their distances to the anchor nodes.

•Compare the received signal strength (RSS) values to determine relative distances.

•If no neighbor is simultaneously further from or closer to all three anchors, assume the node is inside the triangle. Otherwise, assume it is outside.

**Step 4: Position Estimation**

**Estimate Position:**

•Combine the results from multiple triangles to refine the position estimate.

•Use the overlapping region of all triangles where the node is determined to be inside as the estimated area of the node's location.

•The centroid of this overlapping region is taken as the final estimated position of the sensor node.

**Summary**

**Step 1:** Form triangles using anchor nodes.

**Step 2:** Perform inside-outside tests for each triangle.

**Step 3:** Use neighbor distance inquiries to validate the test without physical movement.

**Step 4:** Estimate the position based on the overlapping regions of triangles

1. **Which parameters determine the accuracy of the APIT method?**Node density per radio range
2. **How does the iBeacon protocol work?**  
   The iBeacon protocol works by using specific identifiers within its messages: the UUID, major, and minor values, to uniquely identify a beacon. When a user device receives an iBeacon message, it categorizes the proximity of the beacon into one of four regions: immediate (less than 1 meter), near (1 to 3 meters), far (greater than 3 meters), or unknown. Based on the received beacon information, the user device then consults a server or cloud service to determine the appropriate action to perform, such as unlocking a door or displaying interactive content on a monitor.  
     
   -iBeacon is a Bluetooth Low Energy(BLE) protocol that enables indoor location 9. – 12. – – and proximity services. It works by sending a signal that can be detected by compatible devices, smartphones, tablets, which then use this information to estimate the location of the iBeacon using an application
3. **What are the typical application areas of the iBeacon technology?**It can be used to make automatically opening doors, automatic light systems, etc  
     
   -transportation- can provide information about location of the nearest bus stop, arrival times of the next bus -retail - when a customers enters a shop iBeacons can be used to provide targeted marketing and advertising to customers, depending on the specific part of the store
4. **Why are angulation-based localization methods rarely used in sensor networks?**Angulation-based localization methods are rarely used in sensor networks because they require an array of antennas, which adds complexity and cost to the network
5. **What are the advantages of lateration-based localization methods in sensor networks?**Lateration-based localization methods have the advantage of not requiring additional hardware, making them simpler and more cost-effective to implement in sensor networks.
6. **Sketch how the triangulation method works? Why are three anchor nodes needed**A diagram of a mathematical equation

   Description automatically generatedit is alteration-based localisation method that uses the relative distance between a node and three or more anchor nodes to determine the node’s location. The basic idea is to form a triangle between the node and the anchor nodes, and then to use the geometry of the triangle to determine the location of the node. 3 anchor nodes are needed because we have to forma a triangle in order to determine the location of the node, by adding a third ancho node, the relative distance between the node and each anchor node can be used to form a triangle, which provides enough info to determine the node’s location  
     
   **FROM KID**:  
   The triangulation method, specifically in the context of trilateration for fine-grained node localization, works by determining the position of an unknown node using the known positions of three anchor nodes and the distances to these anchors.

Using the known distances and positions, form three equations based on the **Pythagorean theorem:** A math equations on a white background

Description automatically generated  
These equations can be solved simultaneously to find the coordinates (x, y) of the unknown node P. This is done by transforming the nonlinear equations into a linear system, which can be solved using matrix methods or iterative approaches.

**Why Three Anchor Nodes are Needed:**

**Unique Solution:**

Three points are necessary to triangulate a position uniquely in a two-dimensional space. Each anchor provides a circular area where the node can be located. The intersection of these three circles will give a precise location. With only two anchors, the possible positions form a line, not a point, which results in ambiguity.

1. **What is meant by the term "RSSI"?**RSSI stands for Received Signal Strength Indicator. It is a measure of the power present in a received radio signal, often used to estimate the distance between a transmitter and receiver in wireless communication systems.  
     
   **Alternative**  
   Received Signal Strength Indicator - measure of the power of a radio frequency signal received by an antenna. Used as an estimate of the quality of the wireless link between 2 devices
2. Difference between triangulation and Trilateration
3. **How can RSSI measurements be used to locate sensor nodes?**  
   by measuring the strength of the RF signal from that node to multiple anchor nodes. We use it to calculate the distance between the node and each anchor node, then to determine the node’s location with any localisation method(like triangulation)
4. **What limits the accuracy of the RSSI method**  
   In indoor environments, the presence of obstacles such as walls, furniture etc can cause reflections and scattering of the RF signal, leading to high outliners in the RSSI measurements, which would make it difficult to determine the true distance of the RSSI method
5. Do you know another method for determining the distance between a sensor node and an anchor node? How does this work? **Should we explain, how is the TOA calculated in so on**  
     
   -TDoA(time difference of Arrival) localisation method - measures the time it takes for an RF signal to travel from the node to the anchor node. It workflow is: node sends RF signal that is received by multiple anchor nodes -> each anchor node measures TOA(time of arrival) of the signal and records the value -> the anchor nodes transmit the TOA measurements back to the node or to a central location for processing -> the location of the node is calculated on the differences in TOA measurements between the anchor nodes.
6. **How can scene analysis be used to locate sensor nodes?**  
   Scene analysis is another principle of localization in which fingerprinting is used:  
   Scene analysis is another principle of localization in which fingerprinting is used   
     
   → First collect features of a scene and then estimate the location of an object by matching   
   → Typically features are created by measuring the radio signal strengths (RSS) from surrounding anchor points  
     
   Algorithm consists of two phases   
   → Offline training phase: collects RSS measurements from different pre-known locations and stores them to a database as the training set   
   → Online localization phase: users infers their current location based on the observed RSS measurements, through finding the closest match in the database
7. What are the difficulties with the scene analysis method?  
   requires large amount of power and memory to process the images and extract features in an image, especially in a complex environment, there could be also some limitations with respect to storing a lot of images on the database, for example performance related issues
8. How does satellite-based navigation work in principle?  
   Satellite-based navigation works by using a network of satellites that orbit the Earth and transmit signals to a receiver on the ground. The receiver determines its position by measuring the time delay of signals from multiple satellites, which indicates the distance to each satellite. By knowing the precise locations of the satellites in space and calculating the time it takes for the signals to reach the receiver, it can triangulate its exact position on Earth. This process allows the receiver to accurately pinpoint its location using the data from at least four satellites.
9. What does the term "pseudo-range" mean in the context of satellite navigation?  
   In the context of satellite navigation, "pseudo-range" refers to the estimated distance between a satellite and a receiver. This estimation accounts for the time it takes for a signal to travel from the satellite to the receiver but includes errors due to clock synchronization issues, signal reflections, and other factors. Unlike the true range, which assumes perfect clock synchronization and no signal disturbances, the pseudo-range incorporates these real-world inaccuracies, making it the actual measured value used in calculations to determine the receiver's position.
10. Why exactly are at least 4 satellites needed for satellite-based navigation?  
    At least four satellites are needed for satellite-based navigation to determine the precise 3D position (latitude, longitude, and altitude) of the receiver and to correct the receiver's clock error. Each satellite provides a pseudo-range measurement, which is the distance between the satellite and the receiver. By using signals from at least four satellites, the receiver can solve four equations simultaneously to find the three Cartesian coordinates of its position (ux, uy, uz) and the receiver clock offset (δtU). This ensures accurate positioning by accounting for both spatial and temporal errors.
11. **Outline how the iterative determination of the position of a satellite receiver works via 4 pseudo-range measurements!**  
    The receiver begins by determining an initial estimate of its position using rough information like the last known position. It then calculates the pseudo-range, which is the estimated distance between itself and each of the 4 visible satellites. Using these 4 pseudo-range measurements and the known positions of the satellites, the receiver determines its position through a least-squares estimation algorithm. If the result does not meet expectations, the process is repeated to refine the position estimate.
12. **What does the term DGPS mean?**  
    Differential Global Positioning System - method for enhancing GPS signals
13. **What is the purpose of the DGPS technique and how does it work?**   
    a reference station is introduced, which is located at a known location and has a GPS receiver. The RS receives signals and calculates the difference between the actual position and the position calculated by the GPS receivers in the area for better accuracy of position determination  
      
    **Alternative:**The Differential GPS (DGPS) technique enhances the accuracy of position determination by using a reference station and a rover. The reference station is situated at a known, fixed location and equipped with a GPS receiver. It calculates its position using the GPS signals and compares this to its actual known position, determining the error in the GPS signal. This error information is then transmitted, typically via a radio link, to the rover (a GPS receiver at an unknown location). The rover uses this correction data to adjust its own GPS calculations, resulting in a positioning error of less than 1 meter. The accuracy of DGPS depends significantly on the distance between the reference and rover positions.
14. What does the term AGPS mean?  
    Assisted GPS - method for improving the performance of GPS in challenging environments, like urban areas where signals can be weak or obstructed
15. **What is the purpose of the AGPS technique and how does it work?**   
    uses additional information, such as location of nearby cell towers, to assist the GPS receiver in determining its position. Basically it allows instead of downloading the orbital information from satellites, to send it via cell networks  
      
    **Alternative:**  
    The Assisted Global Positioning System (AGPS) enhances the performance of standard GPS by providing faster position fixes. Normally, GPS requires downloading orbital information of satellites, a process that can be time-consuming when done directly from the satellites. AGPS expedites this by sending the necessary orbital data through other networks, typically via cell networks, thus reducing lock-on times from several minutes to just a few seconds. Most mobile handsets support AGPS for these quicker fixes. Additionally, cell towers can provide crude positioning, which helps correct for ionospheric distortions and further improves location accuracy. This integration of cell network data with GPS data allows AGPS to offer significantly faster and more reliable positioning.

**Chapter 5**

1. **Why are classical routing techniques such as the LS algorithm or the DV algorithm in ad hoc networks unsuitable?**
   1. In ad hoc networks, the network structure constantly changes, requiring frequent re-runs of these algorithms, which is inefficient. Also, these algorithms assume that all nodes and weights are known, which is not the case in wireless networks.
2. **What advantage and disadvantage do proactive routing methods have over reactive routing methods?**
   1. Advantages: Proactive methods maintain pre-calculated routing tables, avoiding delays in route calculation.
   2. Disadvantages: They require high energy consumption due to continuous updates and large overhead from periodic and triggered updates.
3. **Is OLSR a proactive or a reactive routing method?**
   1. OLSR is a proactive routing method because it maintains route tables to all possible nodes
4. **Which optimizations are used in the OLSR compared to classic link state routing methods**
   1. OLSR reduces overhead by using Hello messages for 1-hop neighbours and topology control (TC) messages forwarded only by Multipoint Relays (MPRs), limiting the nodes that need to process these messages
5. **Define the term “Multipoint Relay set”**
   1. A set of 1-hop neighbors that can forward Topology Control messages to all 2-hop neighbors.