1. How does a new node join the Pastry network?

- Node X wants to join
- Determine NodeID id of X (place in the overlay)
- Send JOIN message to topologically nearest node Z
- Feed-in the JOIN message at the “neighbor” A0
- At A0: ■ Node X copies Neighbor-Set from node A0 ■ Node A0 routes message to node Z
- AtAi: ■ Each node sends row i in routing table to X
- Node Z copies its Leaf-set to Node X

2.How do Pastry nodes detect and handle node failures?

- Detection:

  ■ **Periodic verification of nodes in Leaf Set** ■ **Route query failures**

- Replacement of corrupted entries ■ Leaf-Set

- Choose alternative node from Leaf (L)
- Ask these nodes for their Leaf Sets

■ Entry $R_{x\ y}$ in routing table failed:

- Ask neighbor node $R_{x\ i}$ of same row for route to $R_{x\ y}$ ▪ If not successful, test entry $R_{x++\ i}$ in next row

3. Describe the tree-based division principle in CAN.

Each zone is node in a binary tree

Each level stands for a division-step

When dividing a zone

Delete node of that zone, Replace it with new subtree for the two new zones, Division is performed according to sequence of dimensions

4. Explain step by step the failure recovery mechanism of CAN.

If a node does not receive update information of a neighbor Y

Initiate timer in proportion to size of own region

When timer expires, send Takeover message to Y’s neighbors → Node X with smallest zone sends Takeover message first

Node X takes over the zone of Y

-If dimensions match, merge it

-Otherwise X has to manage both zones

5. Why is proximity in structured P2P systems an important property?

- Reduced path latency (avoid intercontinental links, etc)

6. The authors claim that flexibility is a crucial characteristic. What is flexibility, how can it be determined and how flexible are the particular systems?

Flexibility is the algorithmic freedom after the routing geometry has been chosen

Flexibility can be determined in terms of neighbor and route selection

Neighbor selection; Hypercube: 1, Tree, Ring: 2^(i-1)

Route selection Tree: 1, Hypercube, Ring: log n

7. What are Proximity Neighbor Selection (PNS), Proximity Route Selection (PRS) and Proximity Identifier Selection (PIS)? Can these approaches be applied to Chord? Explain why (not)?

- PNS:
  - Routing table entries are chosen based on proximity.
  - Can be applied to Chord
- PRS:
  - The choice of the next hop depends on the proximity.
  - Can be applied to Chord
- PIS:
  - Pick identifiers based on geographic location.
  - Can be applied to Chord

8. Your task is to design a system that uses i3 to handle host mobility. The problem of host mobility with IPv4 is that when a host moves from one network to another, its IP address changes so it is no longer reachable under its old address. With i3, applications use i3 IDs instead of IPv4 addresses to communicate.

a) How can you handle mobility in i3 such that the i3 ID of a host stays the same while the IPv4 address changes?

- Applications use i3 IDs instead of IPv4 addresses as source/destination addresses. When a node changes its network attachments and thus its IPv4 address, it updates its trigger.

9. How should the system be designed to avoid high routing latencies caused by large network distances between senders, receivers, and i3 nodes?

- Receivers should choose i3 IDs such that they are managed by an i3 node close to them. This can be achieved with 'trigger sampling' by measuring roundtrip times to different trigger IDs.

10. How could you use i3 to reduce the number of packets lost during a mobility update, i.e. when a mobile node changes its IP address?

- Use i3 multicast triggers to have packets delivered both to the old and new IP address of a host until a handover is complete.

11. Assume the following scenario for i3 service composition: a web server S offers web pages to client R via i3. There also exists an advertisement service A which augments incoming web pages with advertisement and a compression service C which compresses incoming web pages and forwards the compressed output. Assume that S, R, A, and C are also the i3 IDs of the respective participants.

a) Describe how S can use i3 service composition to send all its web pages through service A before they are delivered to R. Describe how triggers and the i3 IDs in packets need to be arranged.

- S does not send its data to the destination ID D specified by the client R. Instead, it sends its data with the ID stack A|D so the data is first delivered to A and then to D.

12. Describe how R can use i3 to request web pages from S but have them compressed by C before receiving them.

- R needs to present S with a reply-to ID D to send the web data to. Instead of directly specifying its own ID R, it creates a new trigger with the ID D and associates it with the ID stack C|R. Thus, the packets sent to D first traverse service C before reaching the client R.

13. Explain the difference between actuator, sink and source and point out possible differences regarding the hardware components of each node type.

- source: sensors
- actuator: alarms, temperature regulation
- sink: gateway to other networks/workstation, differences to source/ actuator:
  - more energy
  - duty cycle different

14. In the lecture, the general architecture of a wireless sensor node was introduced. Compare this architecture to the architecture of a modern cell phone and discuss reasons for the major design choices.

- both: batterypowered, radio, processor
- but cell phone: UI, Userinteractionexpected, hardwarecoprocessors etc., batteryeasilyrechargeable

15. Consider the following specs concerning power consumption of a sensor node:

Sleep-mode: 0.08mA
Active: 10mA
Sending (radio): 12mA (additional to active)
Receiving: 9mA (additional to active)
Power source (battery): 2000mAh (voltage specs neglected) Clock Speed: 8MHz

The node performs a 200ms cycle consisting of 195ms inactivity and 5ms during which the node takes a measurement. Furthermore, it sends a packet containing the measurement results in parallel to the above cycle every second. Assume that the node receives a packet after sending a packet without entering sleep mode in between. Each packet consists of 200 bytes. The wireless link has a capacity of 9600bits/s.

How long will this node be alive?

- How long does it take to send/receive one packet?

(200 byte*8 bit/byte) / (9600bit/s) = 1/6 s = 0.166 s

=> send and receive a packet: 2*1/6s = 1/3 s = 0.333 s

- one send/receive every second
- in the remaining 4/6s (~600ms) there are three more sensing cycles
- each second:
  - 0.1666s active+sending
  - 0.1666s active+receiving
  - 3 * 0.005s active = 0.015s active (only sensing)
  - 1-0.1666-0.1666-0.015 = 0.6518s inactive
- average energy consumption (in every second):
  - (active+sending) (active+rcv) (only active) (inactive)
  - (10+12)*0.1666 + (10+9)*0.1666 + 10*0.015 + 0.08*0.6516 = 7.0327 mA
- Life time: 2000mAh/(7.0327mA) = 284.4 h = 11.85 days

16. Name other influences that could shorten or prolong the lifetime of the node.

- wake up time
- dynamic voltage scaling
- temperature (battery)
- node density (medium congestion)

17. Sending one bit of data is equivalent to how many operations regarding energy consumption, i.e. how many operations can be executed for the amount of energy necessary to send one bit?

- Energy for one bit:
- (1bit/(9600bit/s))*(10mA(active)+12mA(radio sending)) = 0.0023 mAs ▶ ▶ How long can we calculate

in this time? 0.0023mAs /10mA

- How many operations is that? 0.00023s*(8*10^6)Ops/s

= 0.00023s = 1840 Ops

18. Not only the microcontroller contributes to the power consumption. What other major components contribute?

- Solution:

Radio, External flash, Sensors

19. What is the principle difference between DSR and AODV? Which one these two protocols is more scalable and why?

- DSR: Source Routing
- AODV: Distance Vector
- Scalability: Source routing is less scalable than distance vector.

20. What are the two main sources of time drift that can be avoided in Reference Broadcast Synchronization?

- Operating System / Buffering
- MAC Backoffs

21. Name three applications/protocols that require accurate time synchronization among nodes?

- TDMA
- Coordinated Wakeup (Duty Cycling)
- Distributed Debugging etc....

22. Lets assume a BVR node A with coordinates (2,4,3) in a network with 3 land marks X,Y,Z. If A wants to send a packet to B with coordinates (4,2,7), and A is unable to find a neighbor closer to B than itself.

- **To which Landmark shall node A forward the packet to?**
- **What is the scope of flooding used by that landmark?**
  - Landmark Y
  - Flooding scope = 2

23. What is a PIN bit in 4BLE? Which protocol sets this bit?

- PIN bit pins an entry in the table →→ it cannot be deleted from the table
- Routing Protocol

24. Consider a 4 bit link estimation implementation with following parameters

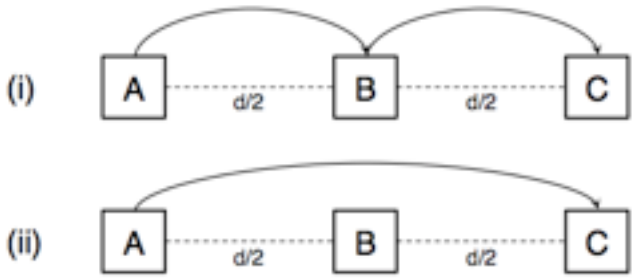
- Nodes update ETX after every 5 transmissions
- ETX is initialized with a value 5
- A node only calculates unidirectional link quality
- Weightage of ALPHA = 0.8 is used

- **What is the ETX of node after the following transmission sequence**
  - 10111110011111100
  - I nitial ETX = 5

- ETX = (0.8) ETX + (0.2) ETX_current
- ETX_current = 1/PRR

25. Multi-Hop vs Single-Hop Communication

Transmitting data to nodes which are out of radio range can be realized by forwarding data over intermediate nodes. The following figure shows a topology where in (i) node A transmits data to C via B (multi-hop) or in (ii) directly transmits to C (single-hop). Assume that the distance between each node is $d/2$.

1. 

a) Describe the relation between the transmitted and received radio signal over the distance in a flat-fading free-space model.

Pr= Ptx/d^2

b) -

26. In-network Processing

Data aggregation is often used to forward an aggregeate instead of full sensor readings.

1. a) Which functions are suitable for aggregation? What information do these functions require in the aggregate?

   min: smallest value

   max: largest value

   sum: sum

   aberage: sum + counter or average + counter

2. b) Why is the *median* not suitable for aggregation?

   all values are needed to compute median

27. Routing and Adressing

a) What is the difference between proactive and reactive routing protocols?

proactive: routing protocols actively maintain a routing topology

reactive: topology is build on demand

b) In which scenario(s) could reactive routing be more feasible than proactive routing?

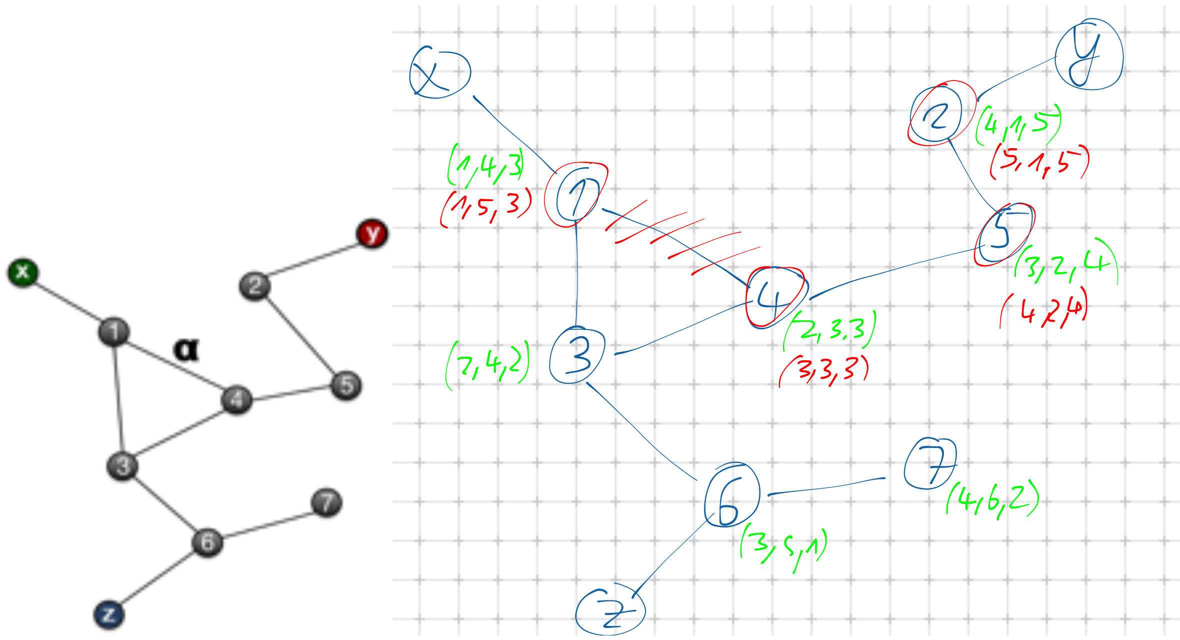
for mobile scenarios/ fast changing network

c) What is the main difference between link-state (source) routing and distance vector routing?

link-state: include complete path packet

DVR: only require information about next hop

d) Given is the following wireless sensor network with the beacon nodes x, y, and z:



What are the addresses (virtual coordinates) of the nodes 1 to 7? The addresses of which nodes change if link α fails? What are the new addresses of these nodes?

28. Link Estimation

a) Why is ETX more suitable than hop count for routing decisions in wireless networks?

hop count: assume that links either works well or not at all many wireless links have intermediate loss ratios

ETX consider also the link qualitiy

b) Briefly describe the purpose of each of the four bits used for Four-bit Wireless Link Estimation (4BLE).

WHILE: Packets on this chanel experience few errors

ACK: A pocket transmission on this link receives an ack

PIN: keep this link in the table

COMPASE: is this a useful link?

29. Localization and Time Synchronization

a) Why is time-of-arrival (ToA) for trilateration problematic for localization in sensor networks? Why is it applicable in other systems, such as GPS?

Determine triangles of anchor nodes where node is inside, overlap them

Check whether inside a given triangle – move node or simulate movement by asking neighbors -> only approximately correct (need clearly geo data)

b) Why is time-difference-of-arrival (TDoA) more suited to trilateration in sensor networks?

Use two different signals with different propagation speeds

Compute difference between arrival times to compute distance

Problem: Calibration, expensive/energy-intensive hardware

c) Why is MAC delay a problem for time synchronization in sensor networks? How can the problem be mitigated?

no exact time sync because of long delay

improvement: Node *i* timestamps its packet after the MAC delay, immediately before

transmitting the first bit

d) Both localization and time synchronization could be solved by using GPS on all sensor nodes. Why is that solution typically avoid?

GPS, something about expensive and energy consumption

30. Sensor Network Deployment

In the lecture we already discussed that deploying WSNs is a challenging task. The paper "Murphy Loves Potatoes: Experiences from a Pilot Sensor Network Deployment in Precision Agriculture" by K. Langendoen et al. published at IEEE IPDPS in 2006 (see L2P learning material section) describes some of these challenges.

a) What problems did the authors encounter during their deployment?

b) How could the problems have been prevented? What additional knowledge would they have needed to prevent those?

c) Could those errors have been prevented *realistically*? Would the knowledge have been available with better preparation, or only in hindsight? Categorize your answers from the previous questions in that respect.

Task 1.2: Properties of P2P systems

a) On which layers of the ISO/OSI model do P2P systems typically reside? What are the advantages of this?

application layer

b) Which specific properties of P2P-systems make them attractive to service providers as well as end users in comparison to Client-Server systems?

good Robustness against failures/ Scalability

c) Content providers employ the P2P paradigm to reduce the server load. How well is the P2P approach suited for different types of content distribution (live-streaming vs. on-demand-streaming vs. file-distribution)? Explain briefly.

live streaming don‘t work very well, but file-distribution work well

Task 1.3: Unstructured P2P systems

a) Why is the original Napster not a pure P2P system? Name at least two major draw-backs of its design.

centralized, single point of fail, no scalibility

b) Why can't the Gnutella protocol guarantee that existing data are found with a search?

search only in TTL - flooding data with time to live

c) Why did the early version of Gnutella have large performance problems? How did Gnutella try to solve the problem? How well did this solve the problem?

flooding inefficent - superpeer

Task 1.4: Properties of Small World Networks

a) What are Random, Small World and Power Law Networks?

random: random node degree

power law P(k)-k^-y

small world: small diameter

b) Name models that create the networks from a) and explain them briefly.

Erdöl realy - Let m,n be a choose of from Gm,n

Gilbert: let Gn,p composed of a vertix with prob. p

Watts - Ring of n nodes, correct back to k

c) Use the Watts-Strogatz-model to create a network with the parameters $n = 6$, $k = 2$, $p = 0.5$.

Task 2.1: Structured Peer-to-Peer Systems

b) What are desired characteristics for DHTs?

based on flat adress space, systems mapped to an id

c) A DHT can employ a direct or an indirect data storage scheme. Explain both schemes briefly and discuss their advantages and disadvantages.

indirect storage: Nodes in a DHT store tuples like (key,value)

direct storage: Content is stored in responsible node for H("*my data*")

d) What are the advantages and disadvantages of the soft-state approach taken by many DHT implementations?

information is only valid for a certain period of time and has to be refreshed

++: node failure detection - easy + quick

--: overhead for refreshing state

e) In many DHT implementations nodes maintain a link to their successor in order to perform the last routing steps. Why is it an advantage to store more than the direct successor of each node?

Resilence against node failures in last routing step - repaining faster when nodes drop out, small speed up if more nodes are directly reachable

Task 2.2: Chord

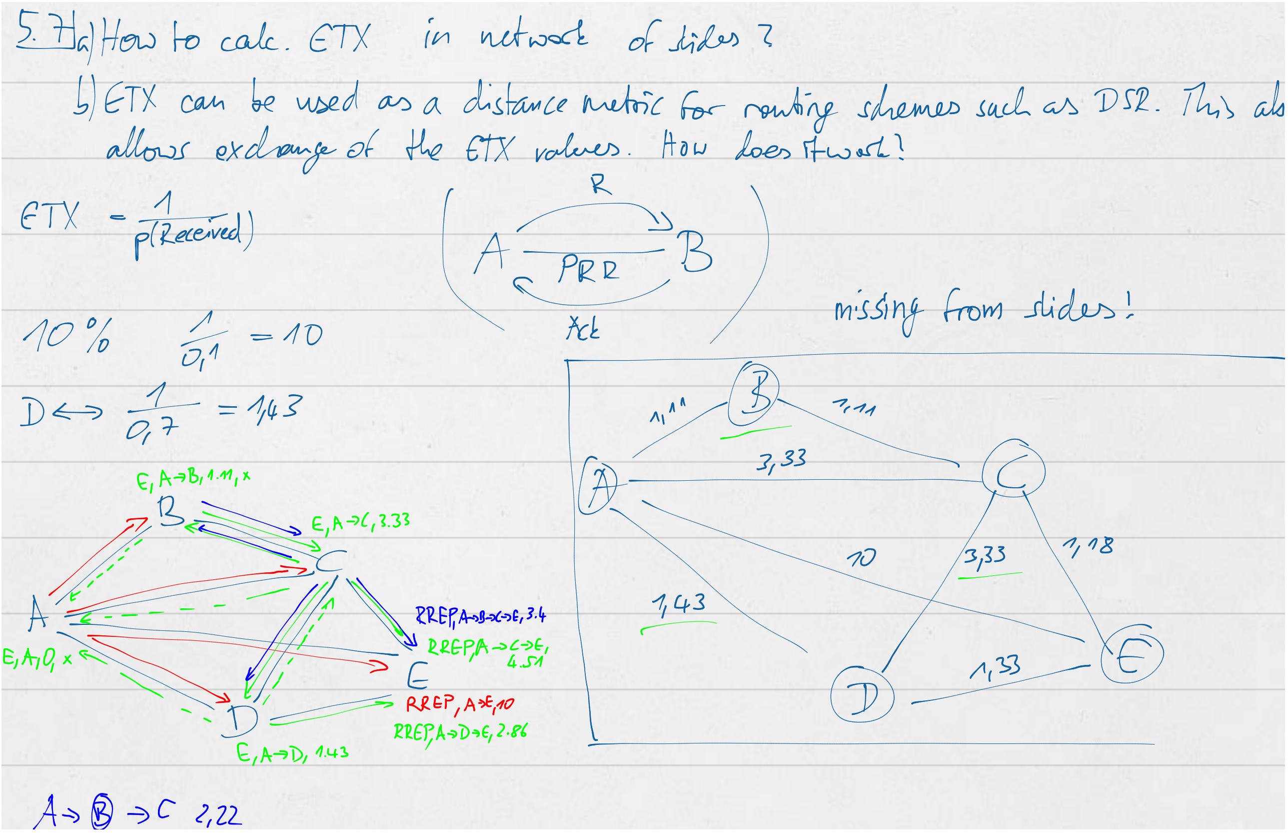
a) Briefly explain the purpose of the finger tables in Chord.

corectly and fast routing

b) Draw a Chord ring with a total capacity of 16 nodes which contains the nodes with ID 1, 2, 7, 10, and 11. Specify the complete finger tables of nodes 1 and 7 and add the corresponding finger links to the ring.

e) A common approach to establish load balancing of frequently requested data items is redundancy. Explain how load balancing can be achieved for storing and retrieving a data item in Chord.

use multiple hash function or distribute equidistantic ring based hash value



Geometry	Algorithm
Ring	Chord, Symphony
Hypercube	CAN
Tree	Plaxton
Hybrid = Tree + Ring	Tapestry, Pastry
XOR d(id1, id2) = id1 XOR id2	Kademlia

	Node degrees	Clustering coefficients	Average path length
random	binomial distribution[1] (≈ normal distribution)	low	low (grows only logarithmically)
Small-World	depends on model[2] (Watts-Strogatz: depends on p[3])	high (by definition)	low (comparable to random graph)
Power-Law	power law distributed (by definition)	varies[4] (Barabasi-Albert: sig. higher than in random networks[5])	low[6]