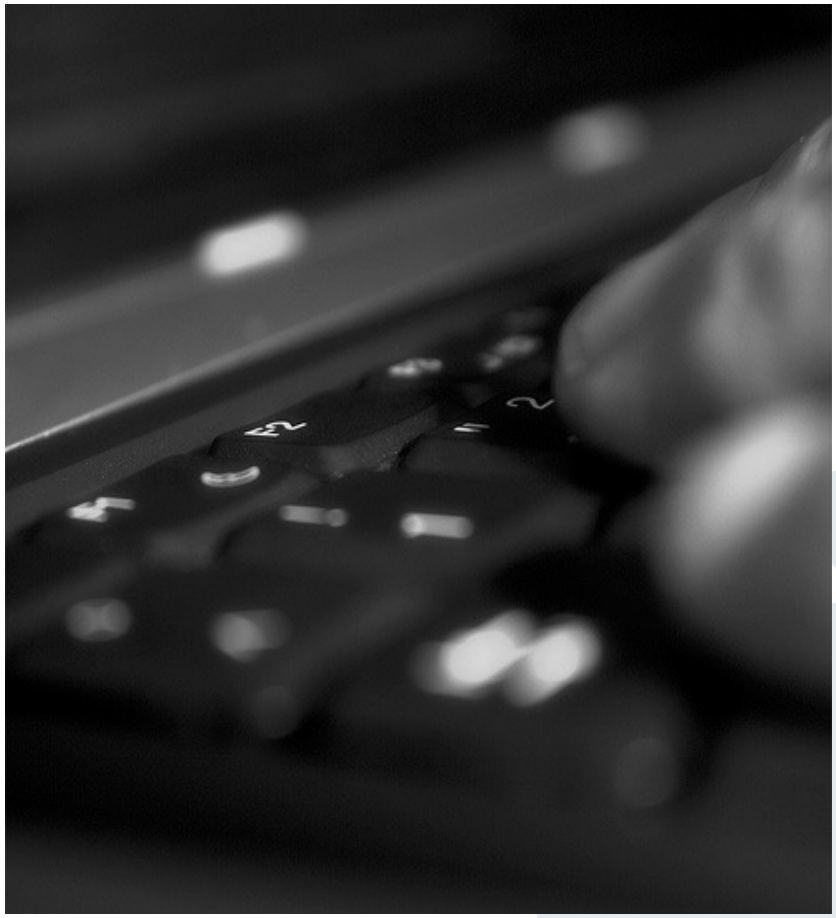
Chair of Mobile Business & Multilateral Security

Exercise 3
Business Informatics 2 (PWIN)

Communication Systems I & II

WS 2023

Frédéric Tronnier
www.m-chair.de



Jenser (Flickr.com)

Studentische Hilfskraft

Aufgabengebiet:

- Unterstützung im Projekt FIIPS@home zum Thema Security in Smart Homes
- Unterstützung bei der Administration der Lehrstuhlwebsiten
- Im Rahmen der Tätigkeit werden Sie uns bei der Durchführung von Lehre und Forschung unterstützen.

Wir bieten:

- eine äußerst interessante, abwechslungsreiche und praxisnahe Tätigkeit
- Einblicke in aktuelle Themen aus Mobile Business, Information Security & Privacy und Identity Management
- an Interesse und Eignung angepasste Aufgabenzuordnung
- die Möglichkeit zum selbständigen und flexiblen Arbeiten

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- gute Kenntnisse in MS-Office
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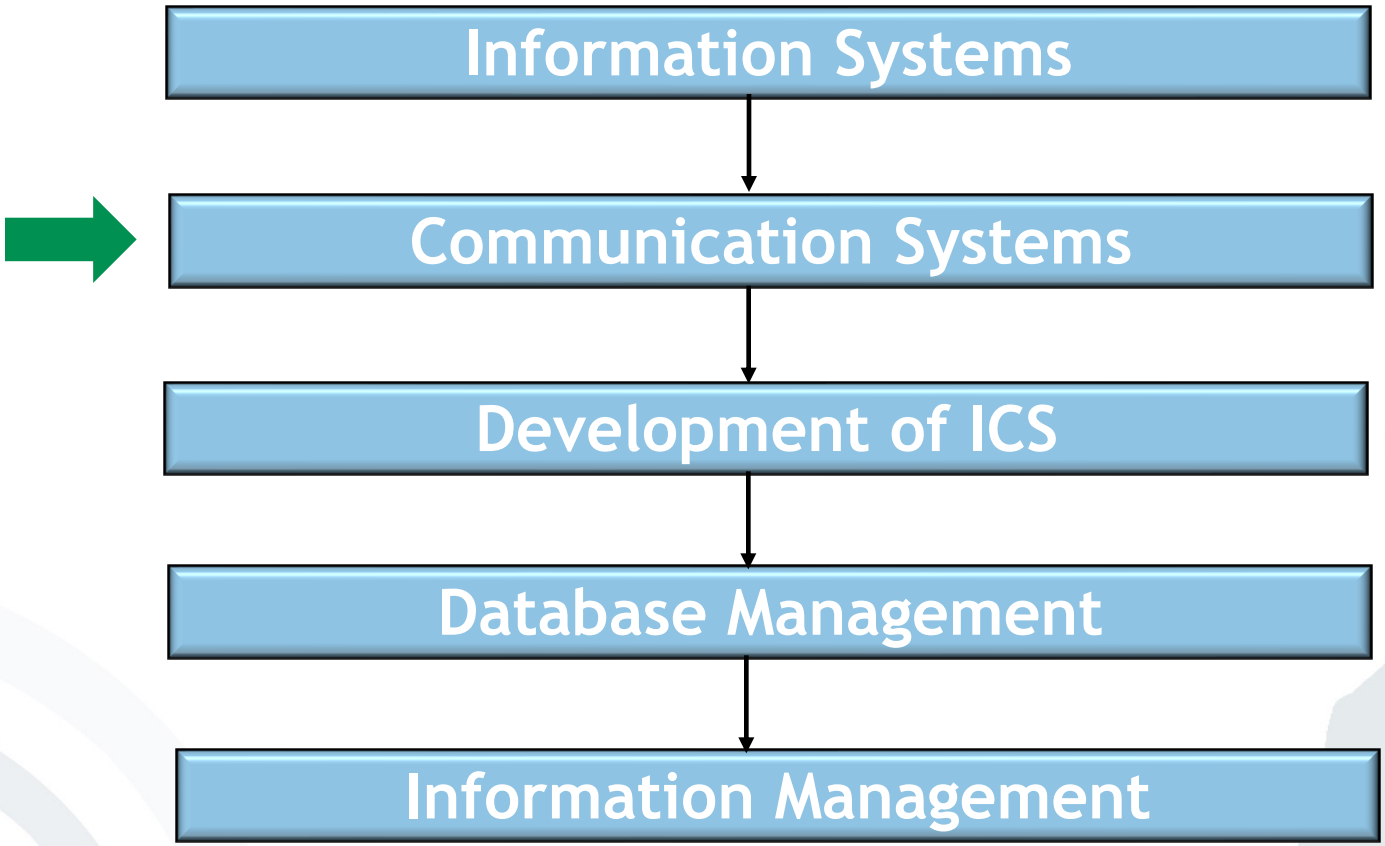
Looking back at Information Systems II & III

By now you should:

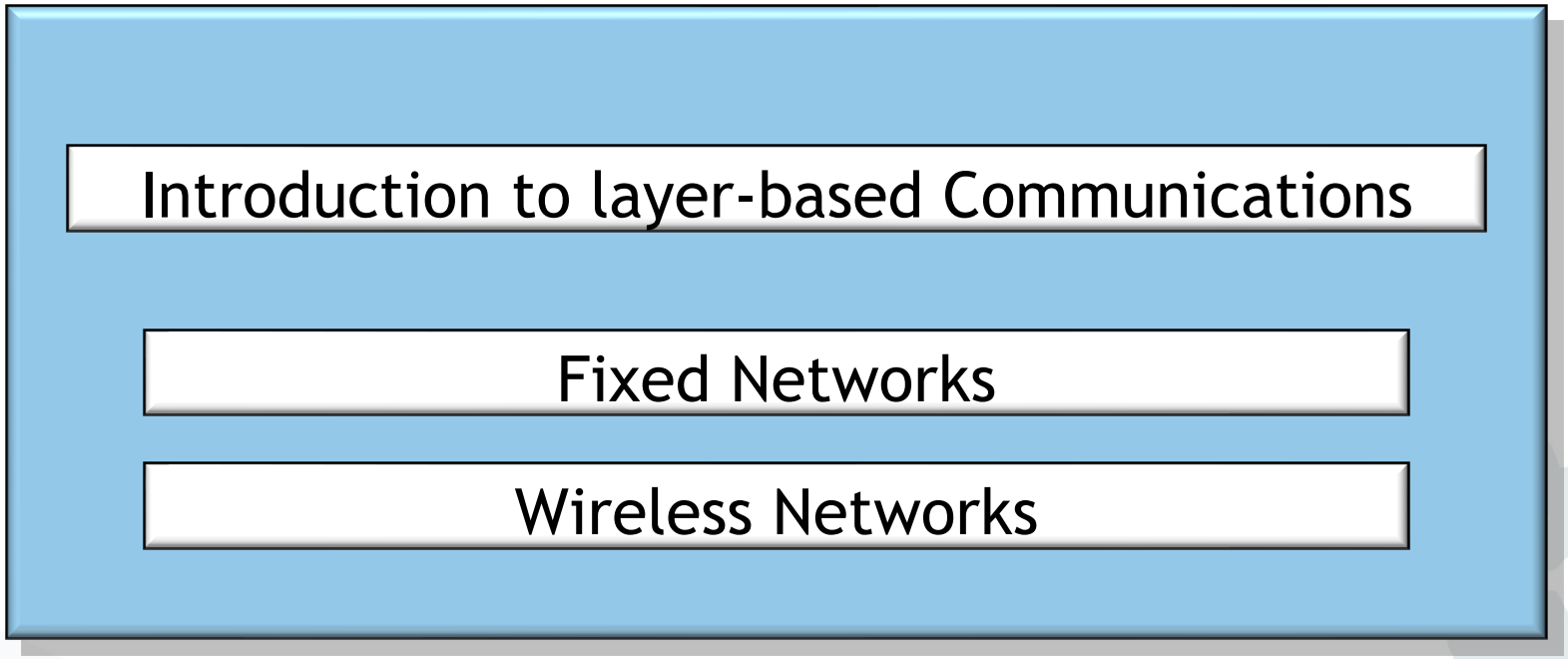
- Be able to explain the three-tier and model-view-controller concept
- Know about different IS architecture concepts (particularly Cloud and Edge Computing)
- Know about the components and characteristics of mobile tech
- Understand prominent mobile business models and be able to explain important tools/mechanisms in this industry.

→ Apply your knowledge!

Components of the Course Business Informatics II (PWIN)



Components of the Course



Agenda

- Exercise 1: Layer-based Communication Models
- Exercise 2: OSI reference Model
- Exercise 3: Network Layer in OSI reference model
- Exercise 4: Wireless communication

Exercise 1: Layer-based Communication Models

a) What is the reason for the development of layer-based communications?

b) How does layer-based communication work in principle?

Exercise 1a): Solution

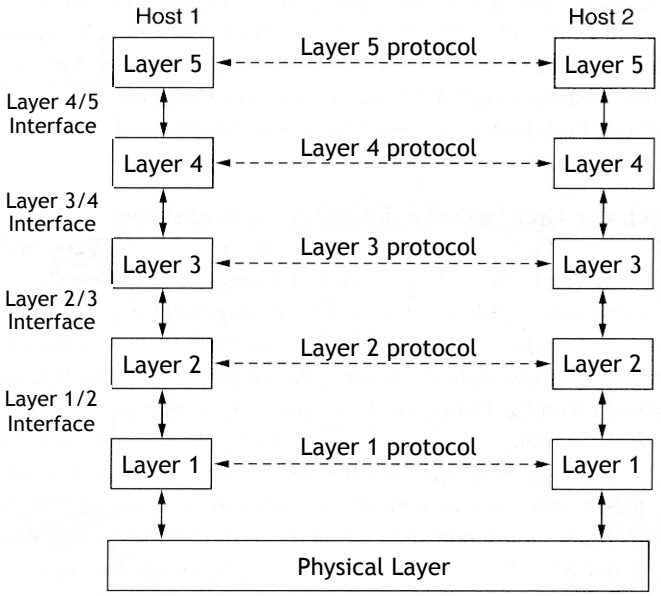
- In order to **reduce complexity** of communication systems, most networks are built using **multiple layers**, one upon the other.
- In all networks, layers provide specific **services** to the layer above while, in particular, shielding it from details such as **how** these services are provided or implemented.
- In informatics, this concept is known from the areas of abstract data types, data encapsulation and object-oriented programming.

Exercise 1: Layer-based Communication Models

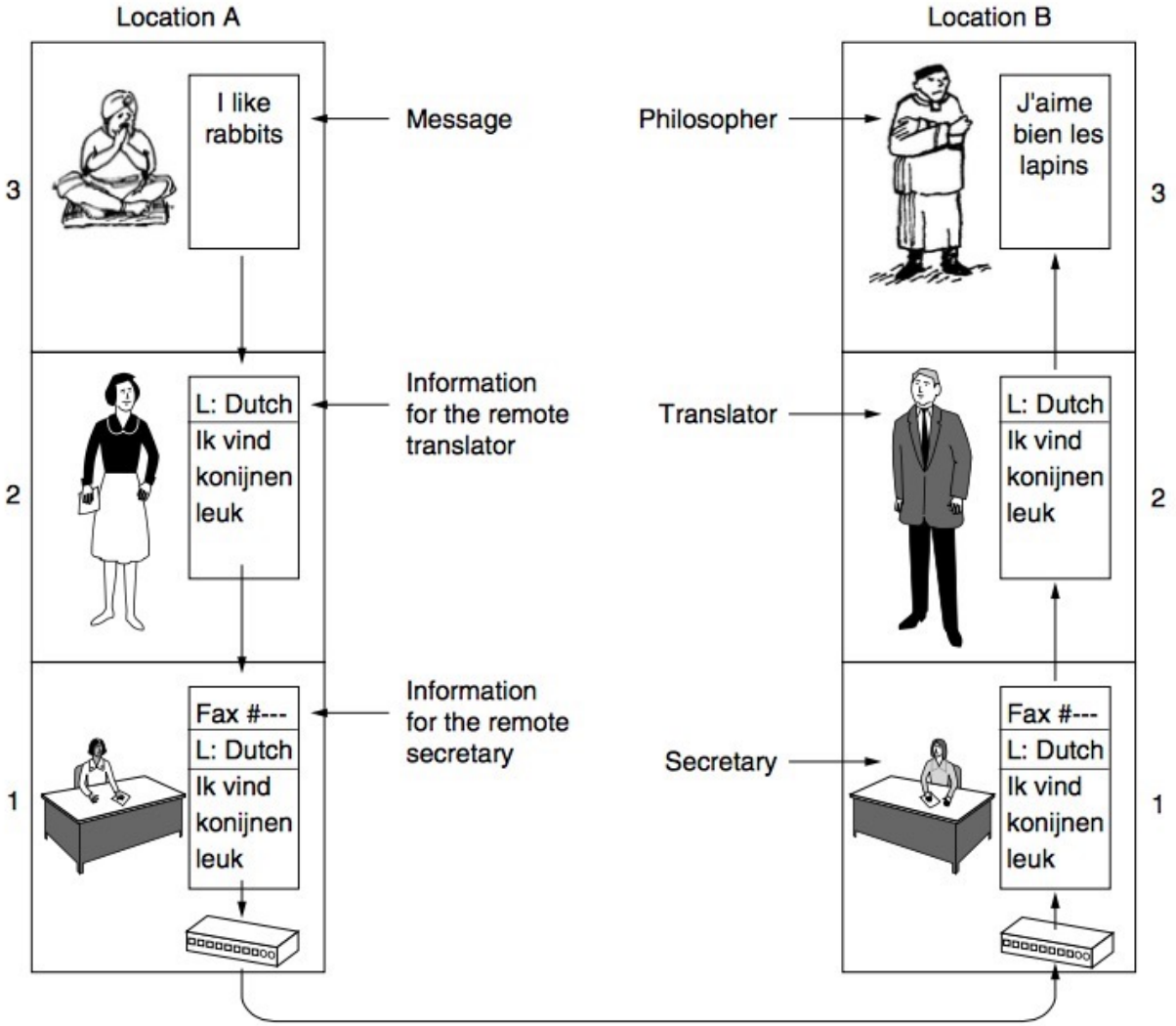
b) How does layer-based communication work in principle?

Exercise 1b): Solution

- Layers provide specific **services** to the layer above.
- Communication inside one layer uses the respective **protocol** of a layer (i.e. rules and conventions, on which the communication is based).
- **No direct data communication** from layer n of one host to the same layer n of another host
- Each layer sends data and control messages to the layer below until the lowermost layer is reached.
- Located below layer 1 is the physical transmission medium which is used for the communication.



Additional info to layer-based communication



Source: Tanenbaum, Computer Networks, pp.31-32 (2011 - 5th ed.)

Additional info to layer-based communication

- Note that each protocol is completely independent of the other ones as long as the interfaces are not changed. The translators can switch from Dutch to, say, Finnish, at will, provided that they both agree and neither changes his interface with either layer 1 or layer 3. Similarly, the secretaries can switch from fax to email without disturbing (or even informing) the other layers. Each process may add some information intended only for its peer. This information is not passed up to the layer above.

Source: Tanenbaum, Computer Networks, pp.31-32 (2011 - 5th ed.)

Agenda

- Exercise 1: Layer-based Communication Models
- Exercise 2: OSI reference Model
- Exercise 3: Network Layer in OSI reference model
- Exercise 4: Wireless communication

Exercise 2: OSI reference model

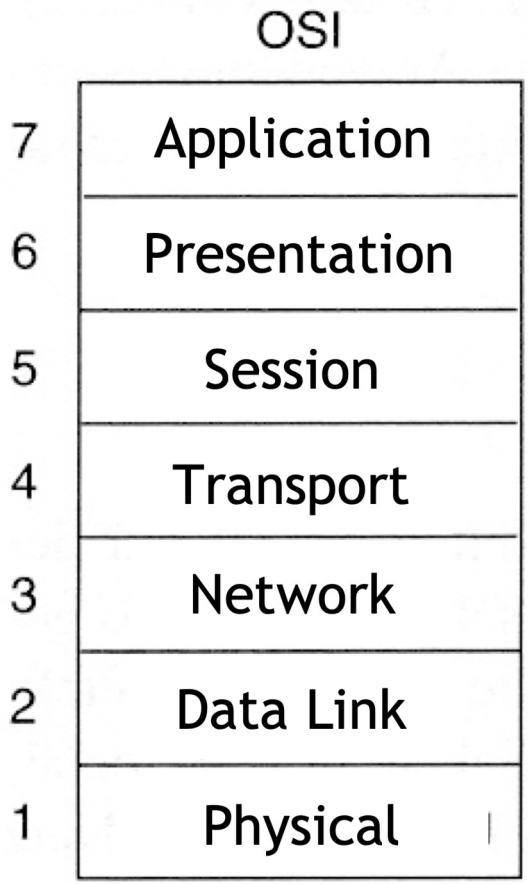
a) The OSI model is a layer model originally proposed by the International Standards Organization (ISO). But what does OSI stand for? Which layers does the OSI reference model contain?

Exercise 2a): Solution

- Development of the OSI model
  - The **OSI Model** is based on a proposal of the **I**nternational **S**tandards **O**rganization (ISO) (1983).
  - In 1995, it was revised (Day und Zimmermann) and is since then named **OSI Reference Model**.
  - OSI means **O**pen **S**ystem **I**nterconnection. Open Systems are open for communication with other systems.

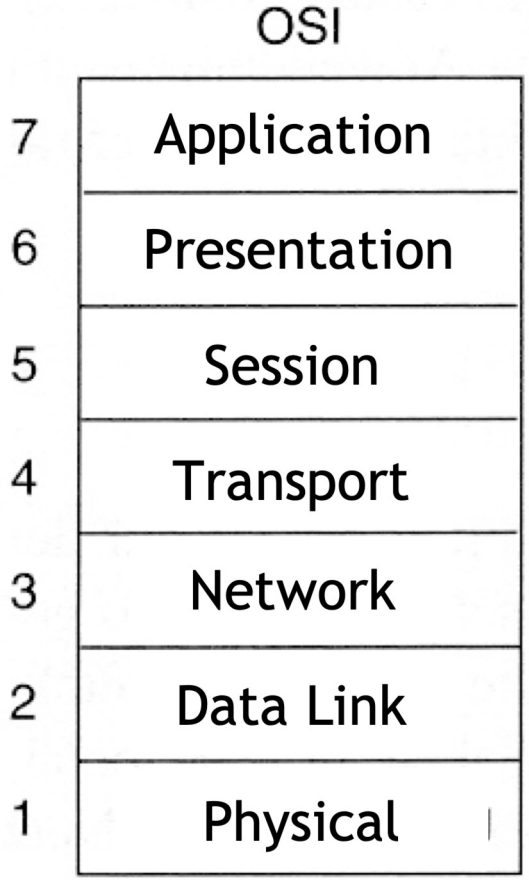
Source: Tanenbaum (2006), p. 54-58

Exercise 2a): Solution



Source: Tanenbaum (2006), p. 54-58

Additional info on OSI Reference Model



All People Seem To Need Data Processing

Memory aid

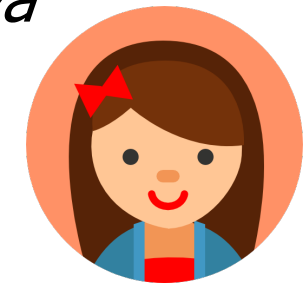
Source: Tanenbaum (2006), p. 54-58

Exercise 2: OSI reference model

b) Briefly explain the information flow in the OSI reference model when a user of InstaMatch sends a message to another user who is not in the same network.

Exercise 2b): Solution

Eva



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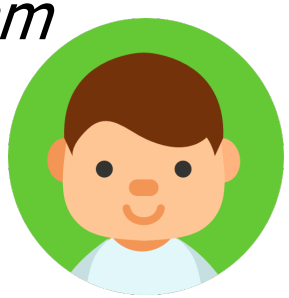
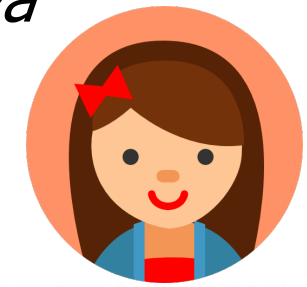
Adam



"I like you, let's meet after the lecture"

Exercise 2b): Solution

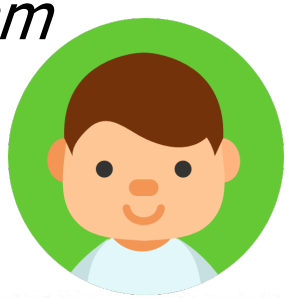
Eva



Application
Presentation
Session
Transport
Network
Data Link
Physical

?

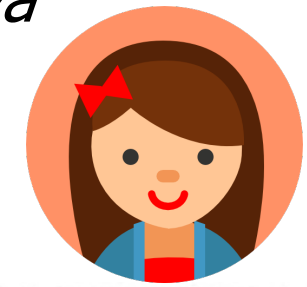
Adam



Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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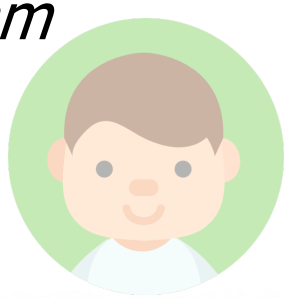

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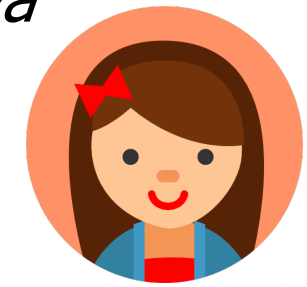
Application
Presentation
Session
Transport
Network
Data Link
Physical

InstaMatch creates the data (message, addresses, etc.) and gets ready to send it using http.

Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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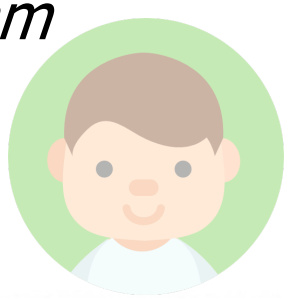


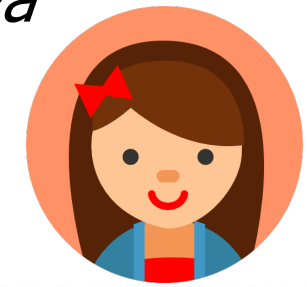
Application
Presentation
Session
Transport
Network
Data Link
Physical

The data is received by the application layer in form of characters and numbers. It translates it into binary (1001011…).

Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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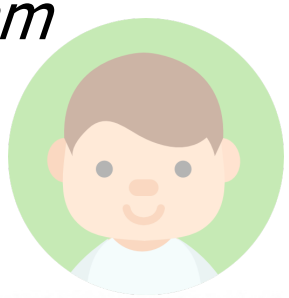
Adam



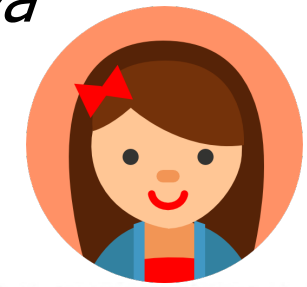
Application
Presentation
Session
Transport
Network
Data Link
Physical

A session connection is started.

Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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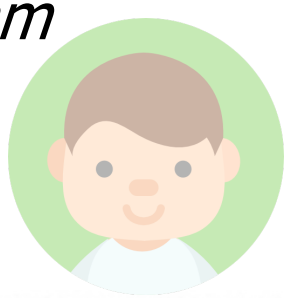
Adam



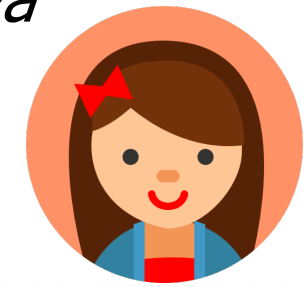
Application
Presentation
Session
Transport
Network
Data Link
Physical

TCP is used to ensure an ordered an complete transfer of the data. For this it is divided into smaller segments and source and destination are added.

Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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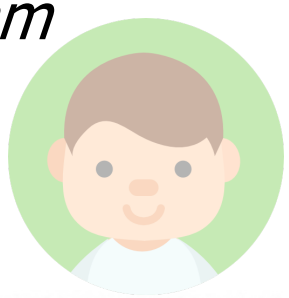
Adam



Application
Presentation
Session
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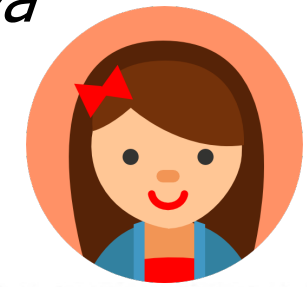
Network
Data Link
Physical

Adam's IP address and Eva's IP address are added to each segment to form a packet. The best path through the network is selected and the data packets forwarded (routing).

Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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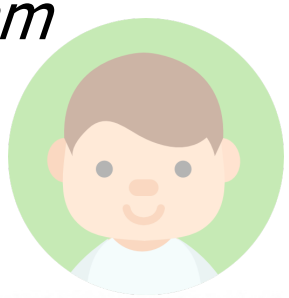
Adam



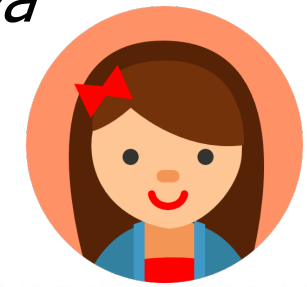
Application
Presentation
Session
Transport
Network
Data Link
Physical

Eva's and Adam's MAC addresses are added to form a data frame, which are transmitted in an efficient and reliable way.

Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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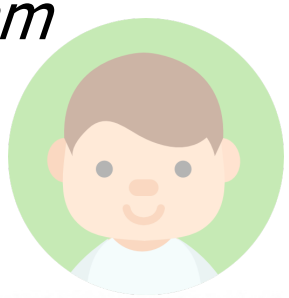
Adam



Application
Presentation
Session
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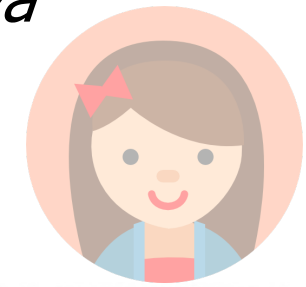
Network
Data Link
Physical

Bits are worked into radio signals and transferred over the air to Adam.

Application
Presentation
Session
Transport
Network
Data Link
Physical

Exercise 2b): Solution

Eva



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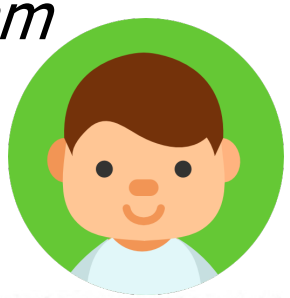
Adam



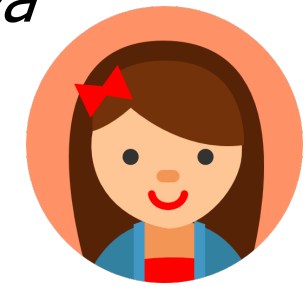
Application
Presentation
Session
Transport
Network
Data Link
Physical

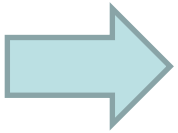
Adam receives radio signals and the data is processed in reverse order through his 7 layers.

Application
Presentation
Session
Transport
Network
Data Link
Physical

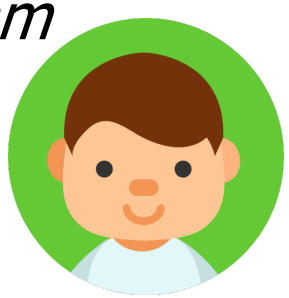
Exercise 2b): Solution

Eva



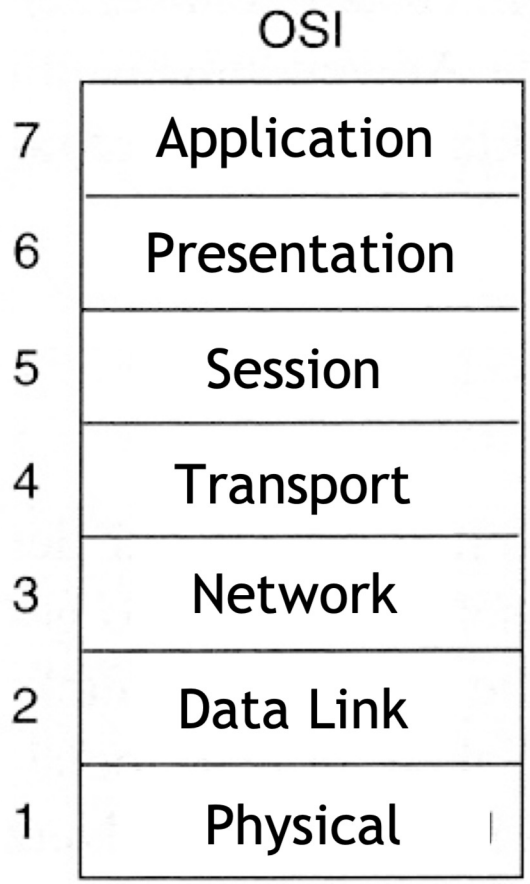


Adam



Eva says: “I like you, let’s meet after the lecture”

Keywords for OSI reference model layers



SMTP, HTTP

Encryption, Compression

Session

TCP (3 way handshake), UDP

Routing, IP address

Frames, MAC

Bits, LAN cable, optical fibre, air

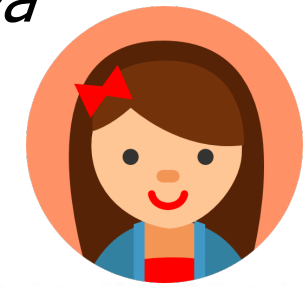
Exercise 2: OSI reference model

c) The MAC address plays an important role in the Data Link Layer. What is it and who assigns it to what?

Source: Tanenbaum, Computer Networks, pp.31-32 (2011 - 5th ed.)

Exercise 2b): Solution

Eva



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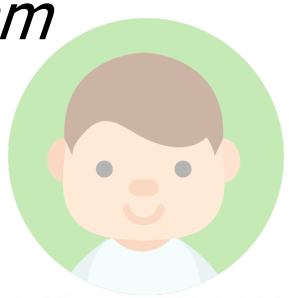

Application
Presentation
Session
Transport
Network
Data Link
Physical

Eva's and Adam's MAC addresses are added to form a data frame, which are transmitted in an efficient and reliable way.

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Layer 2: Data Link Layer
MAC Address

Media Access Control address (MAC address)

- Globally **unique identifier** for a network interface (“hardware address”)
- Used on physical networks such as **ethernet**, **wireless LANs (Wi-Fi)**, **bluetooth** and fibre-based technologies
- Assigned by manufacturer of the interface
- Length of the identifier: **6 byte (48 bit)**
- Network devices (e.g. switches, network adapter) need MAC addresses in order to be explicitly addressed on layer 2 if required by a service on higher layers.
- MAC addresses of Wi-Fi network interfaces are some-times used to allow or restrict access to Wi-Fi networks.

Agenda

- Exercise 1: Layer-based Communication Models
- Exercise 2: OSI reference Model
- Exercise 3: Network Layer in OSI reference model
- Exercise 4: Wireless communication

Exercise 3: Network Layer in OSI reference model

a) The main task of the Network Layer is *routing*. Please explain what routing is. How does the routing algorithm Dijkstra work?

Exercise 3a): Solution

- Routing is the process of selecting paths and forwarding packets while making sure the best possible path to the destination network is used.

- Best possible means:
  - Low transport costs
  - Fastest possible transport
  - Bug-proof transmission
  - Weighted according to a combination of criteria above
  - etc.
- Various routing algorithms exist:
  - **Dijkstra Algorithm**
  - Bellman equation (“Principle of Optimality”)
  - Ford Algorithm

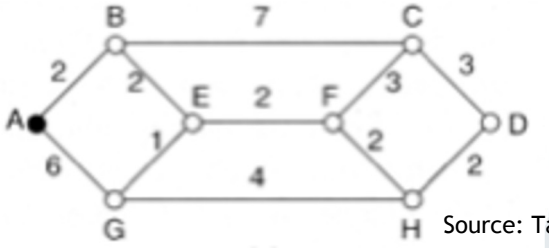
Source: Tanenbaum (2006)

Exercise 3a): Solution

Vertex = Knoten
Edge = Kante

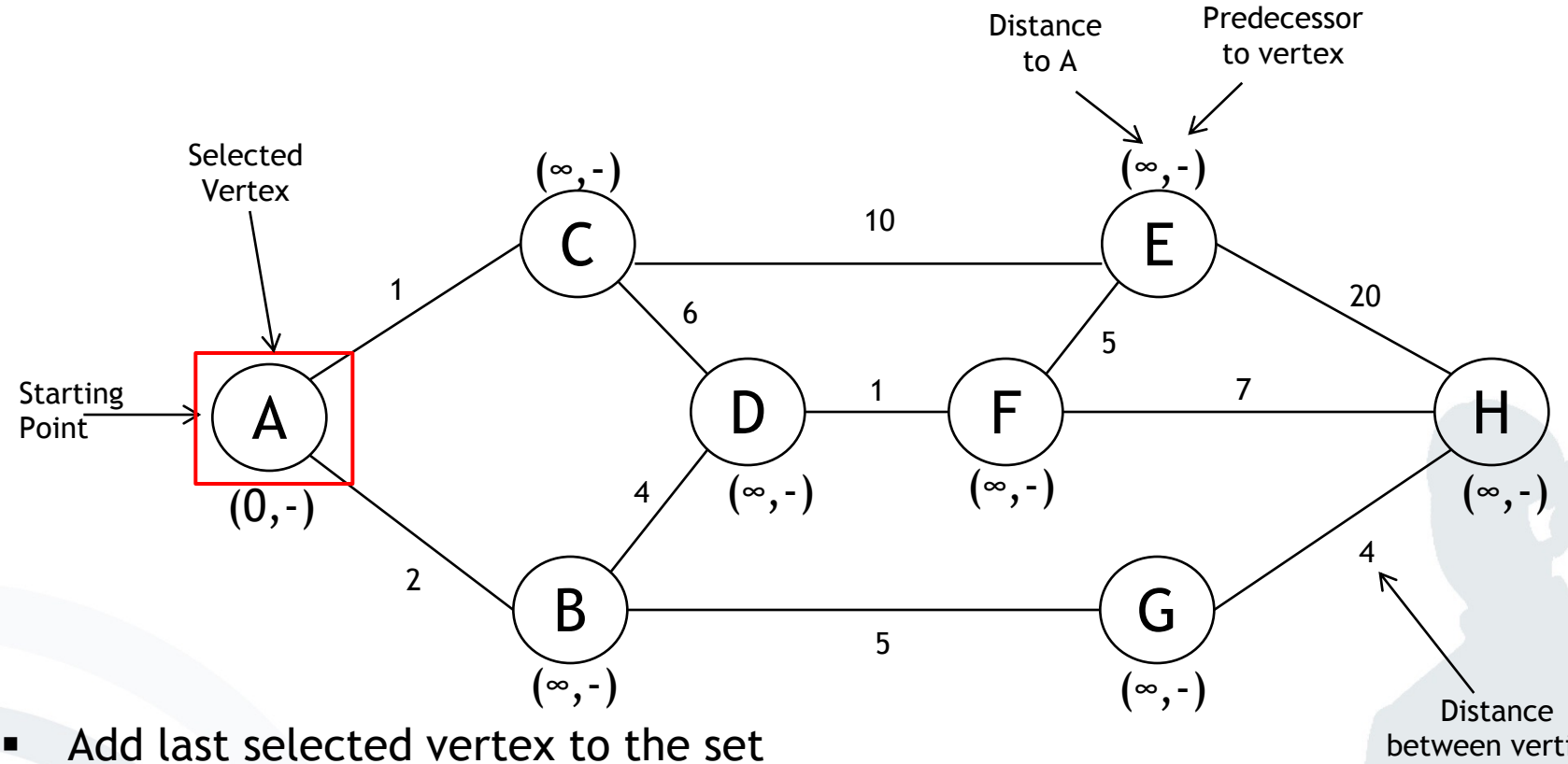
Dijkstra Algorithm

- The algorithm was developed 1959 by Edsger Wybe Dijkstra.
- It solves the problem of finding the shortest path between two vertices *(singular: vertex)* in a graph.
- For this concept, a graph is created in which every router is represented by a **vertex** and every transmission line by an **edge**.
- The algorithm computes the shortest path between a selected pair of (two) routers with the help of this graph.
- The labels of the **edges** can e.g. be distance, bandwidth, average traffic, transmission costs, average queue length, average transmission time measured or other factors.
- Every **weighted edge** has an impact on the shortest path.



Source: Tanenbaum (2006), p. 391-393

Layer 3: Network Layer Using Dijkstra Algorithm



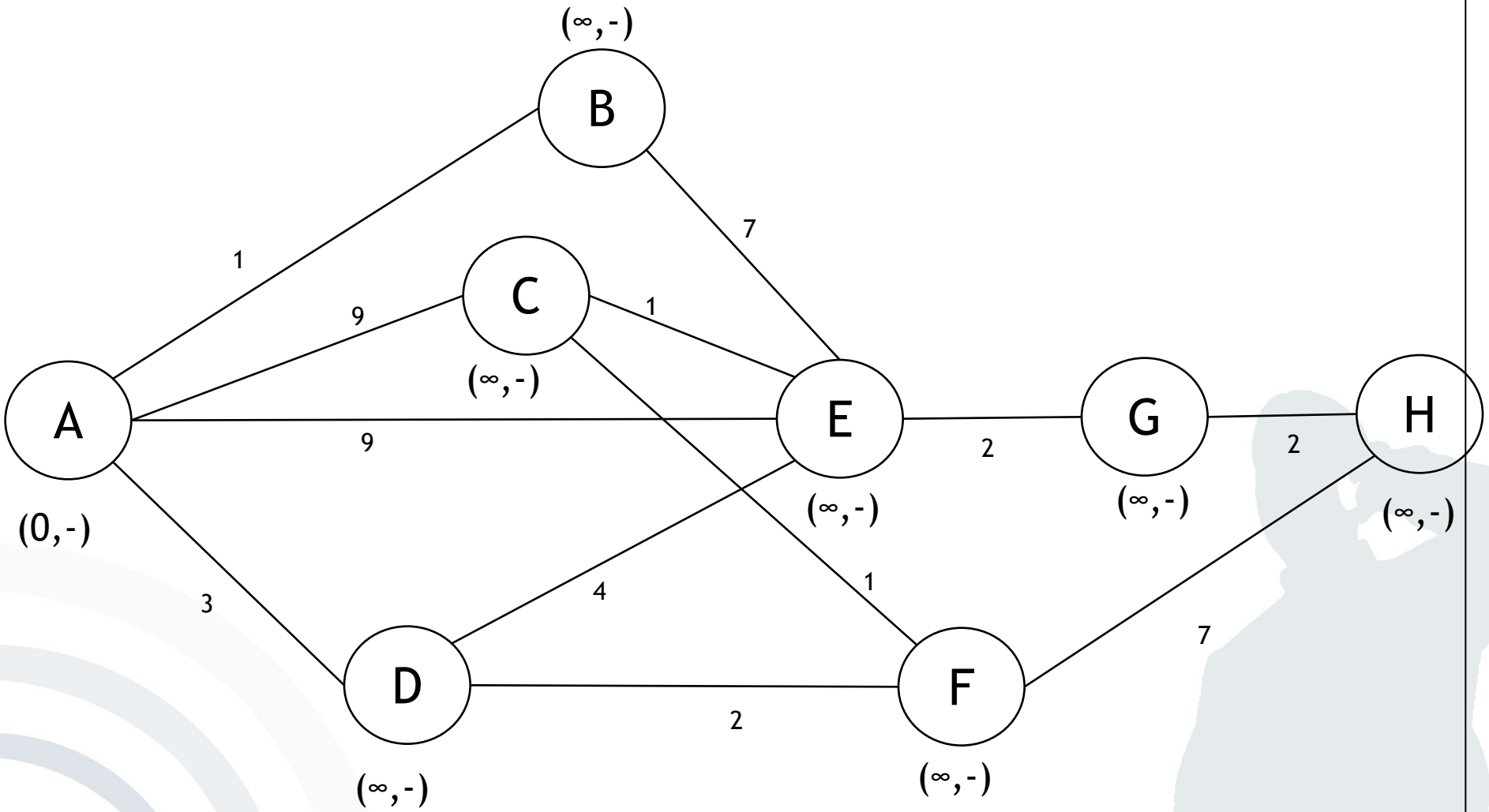
- Add last selected vertex to the set
- If shorter (longer), update distance and predecessor values of the neighbours of the last selected vertex
- Select the vertex, which is not in the set and has the minimum (maximum) value

Exercise 3b): Routing – Dijkstra Algorithm

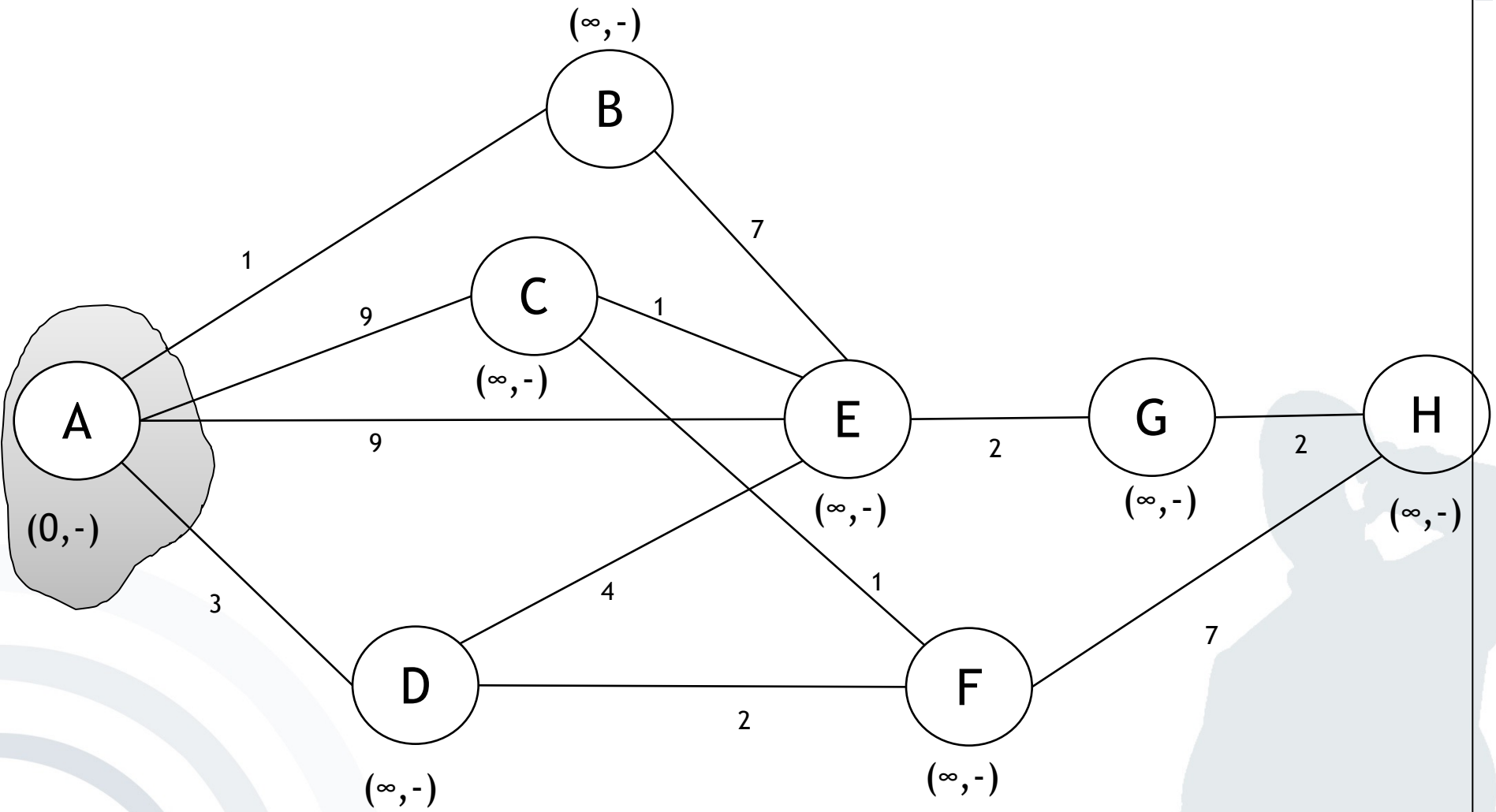
b) Assume when using the InstaMatch service, a text message to a dating partner has to be passed through various systems before it reaches its destination. Since it is critical to reach the recipient in time, calculate the shortest path (from person “A” to person “H”) based on the *Dijkstra algorithm*.

Please note that lower case letters denote *system vertices* and numbers denote the *milliseconds* it takes for a message to travel between two system vertices.

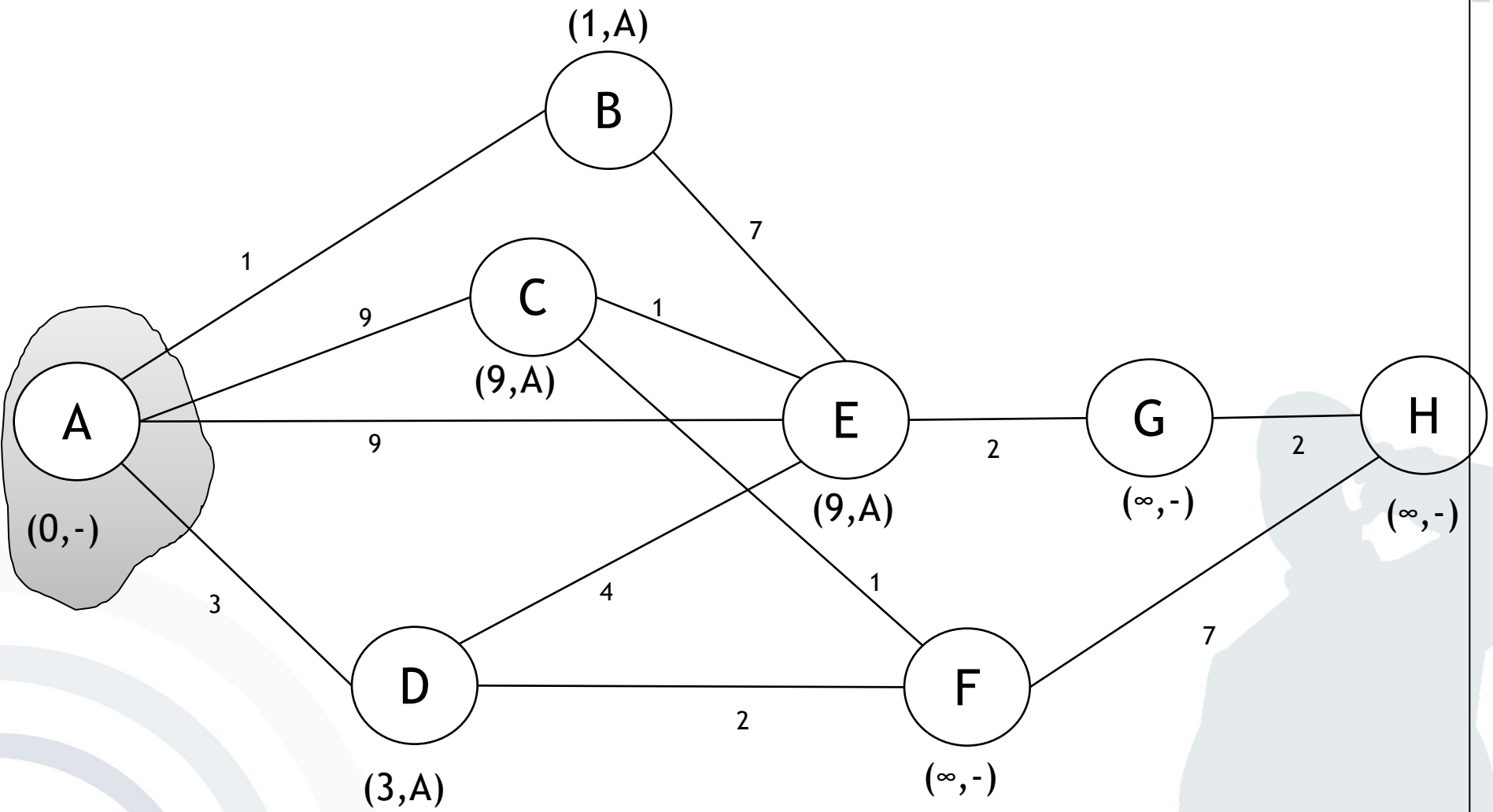
Exercise 3b): Solution



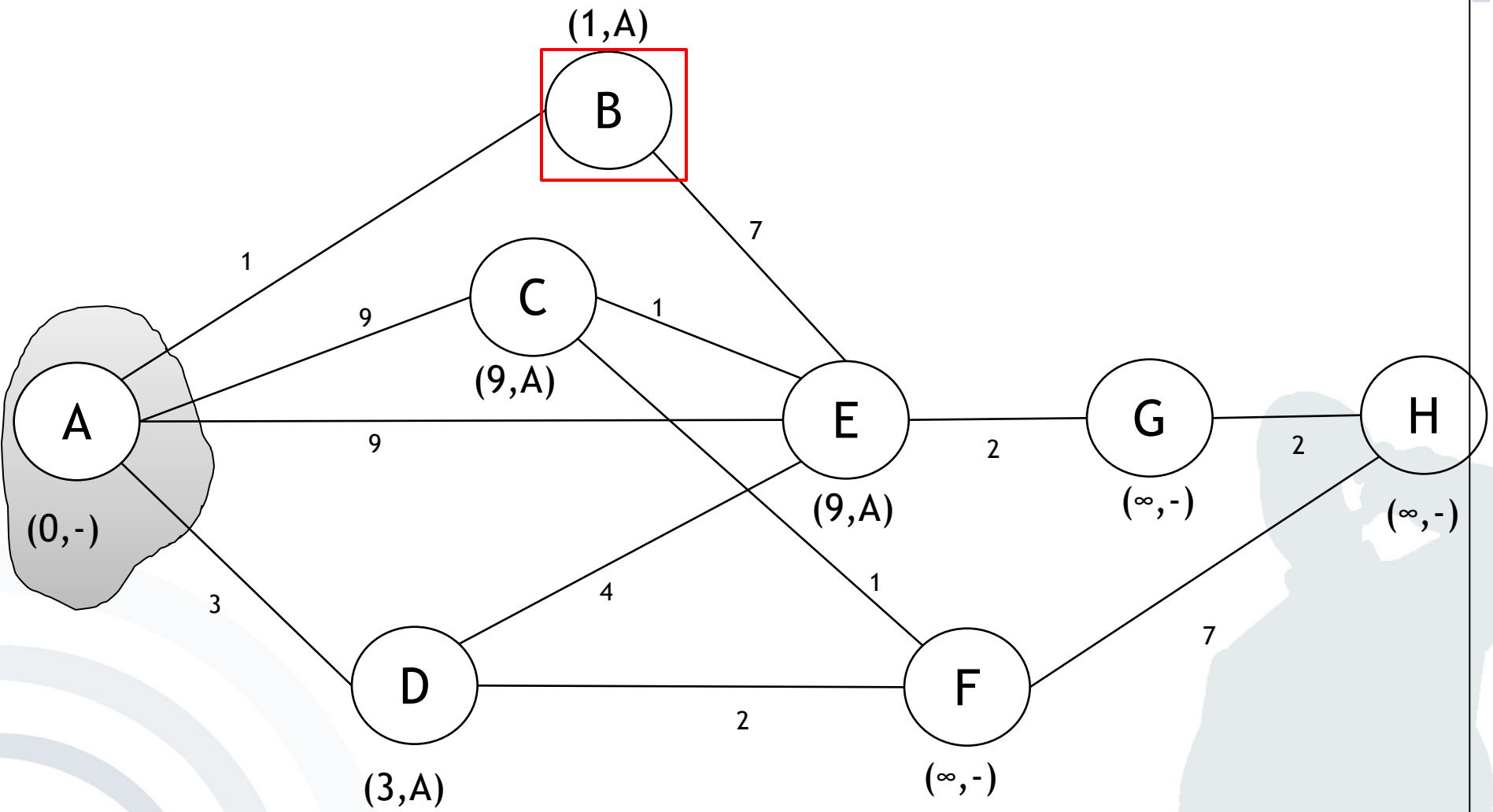
Exercise 3b): Solution



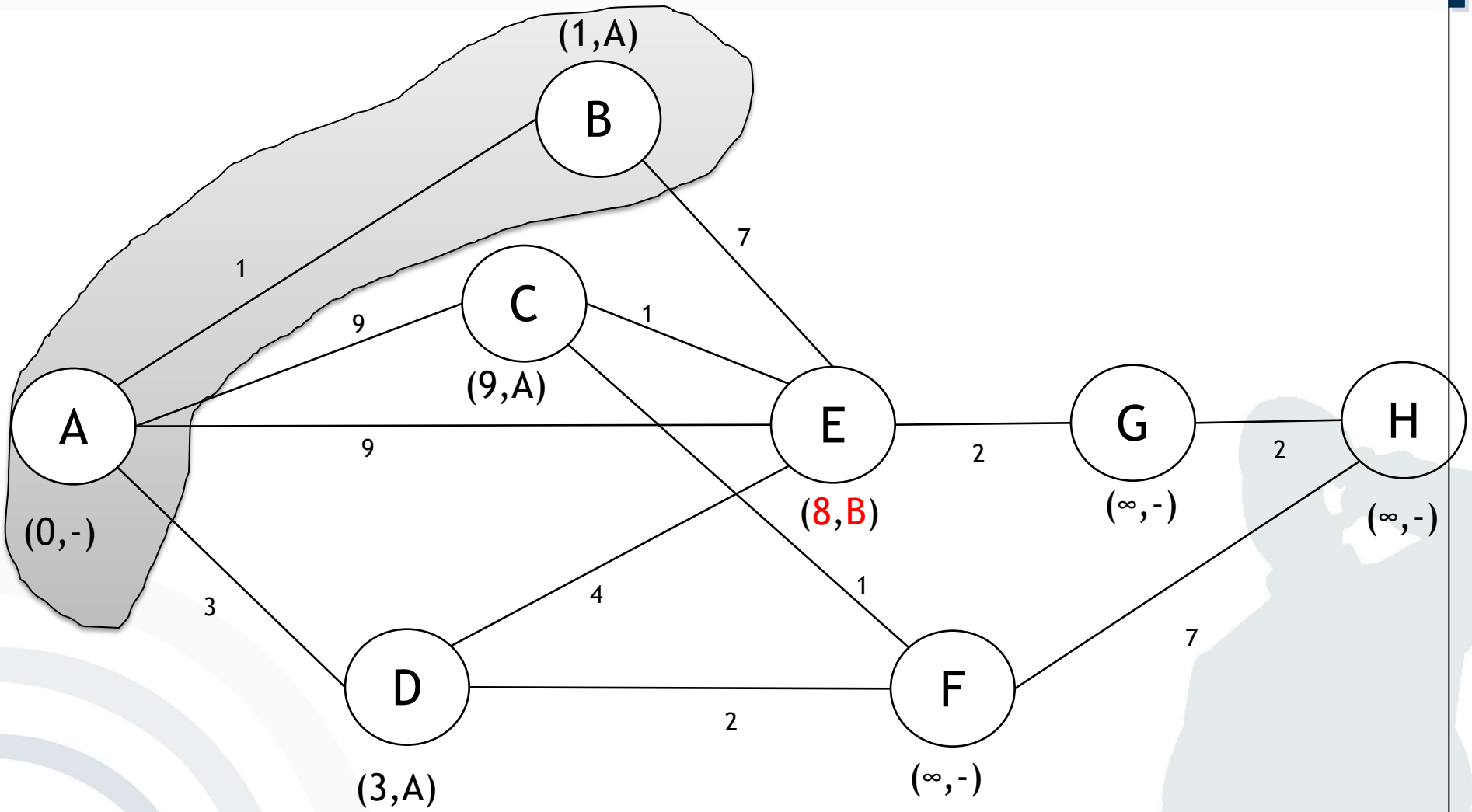
Exercise 3b): Solution



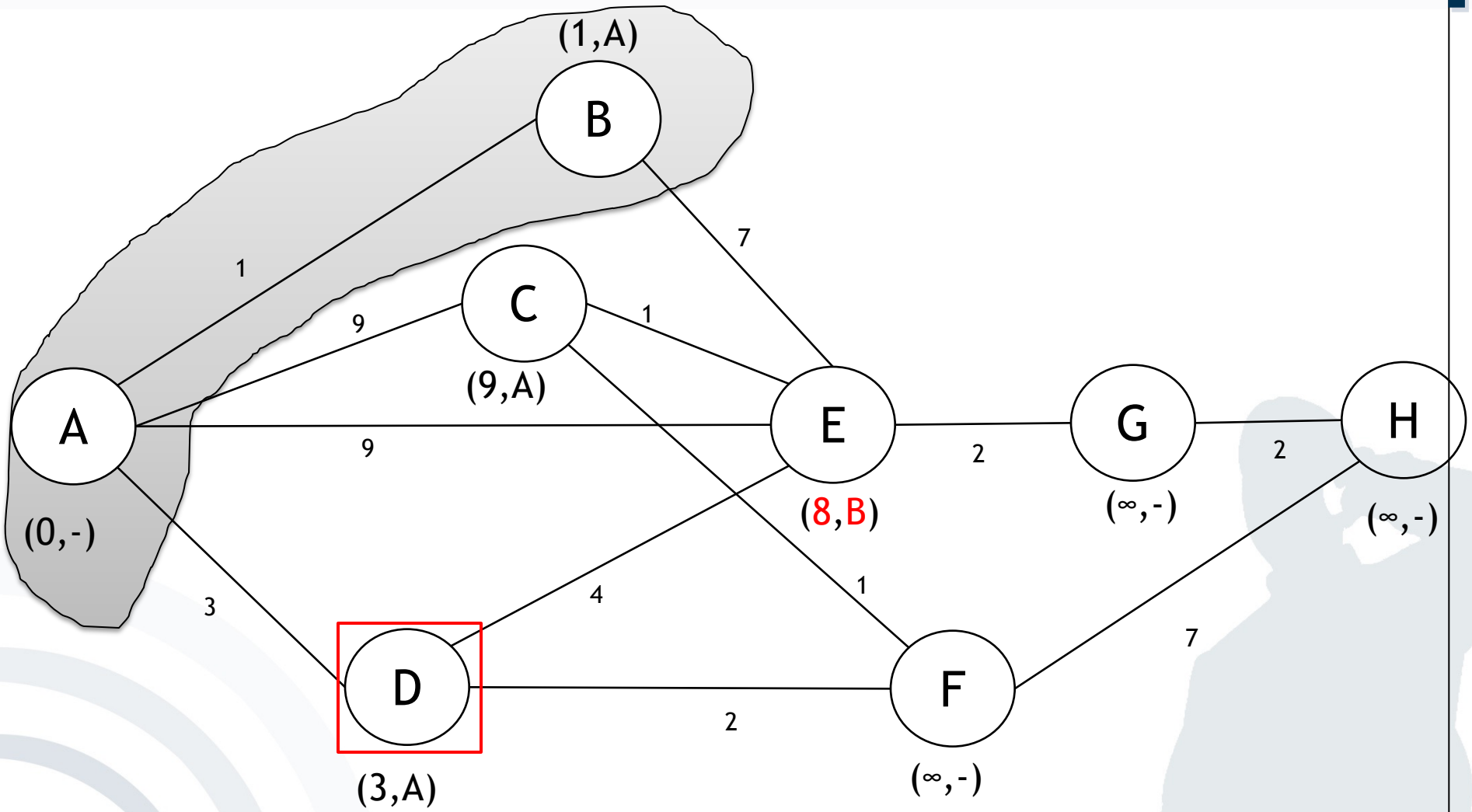
Exercise 3b): Solution



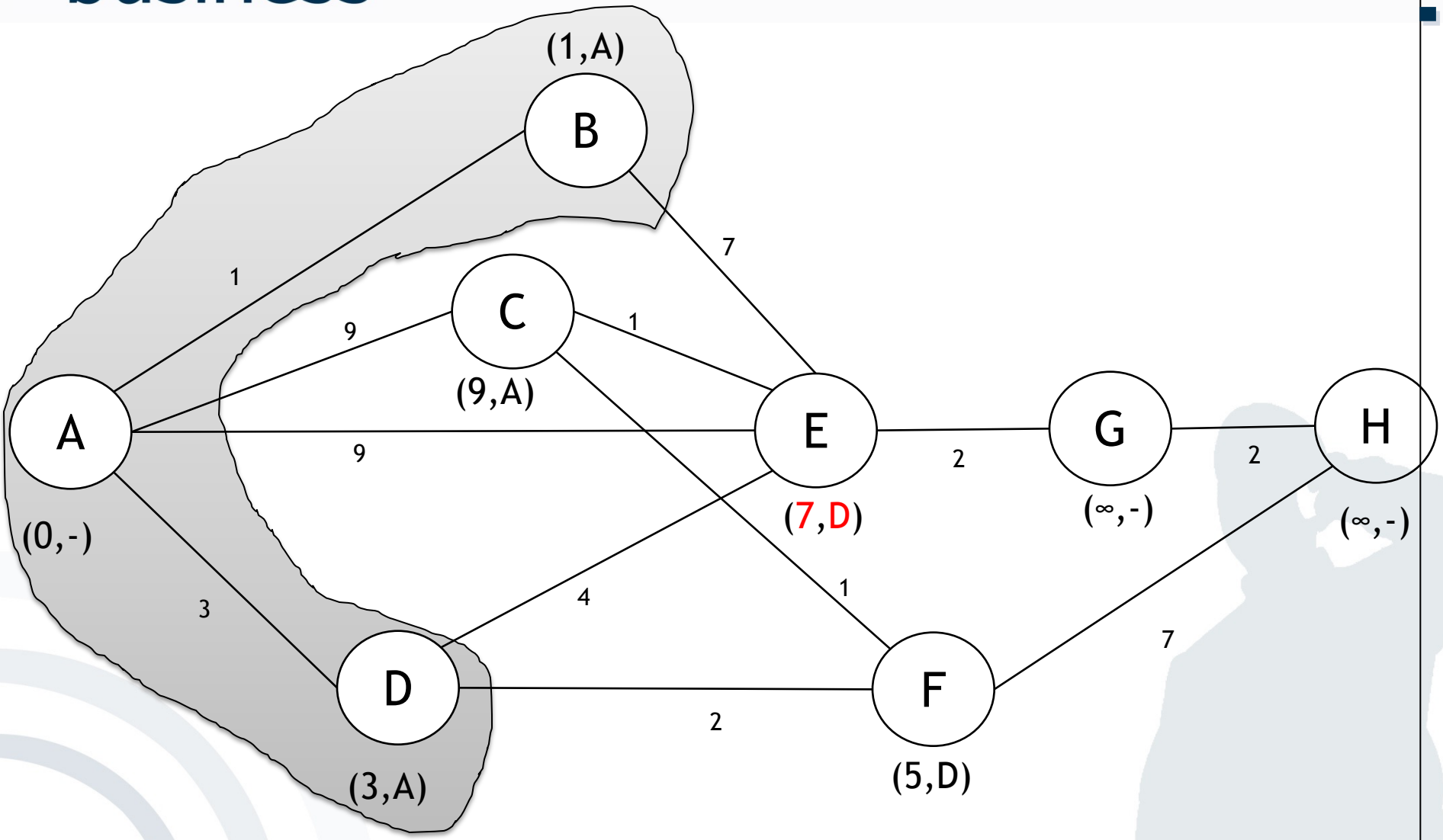
Exercise 3b): Solution



Exercise 3b): Solution



Exercise 3b): Solution



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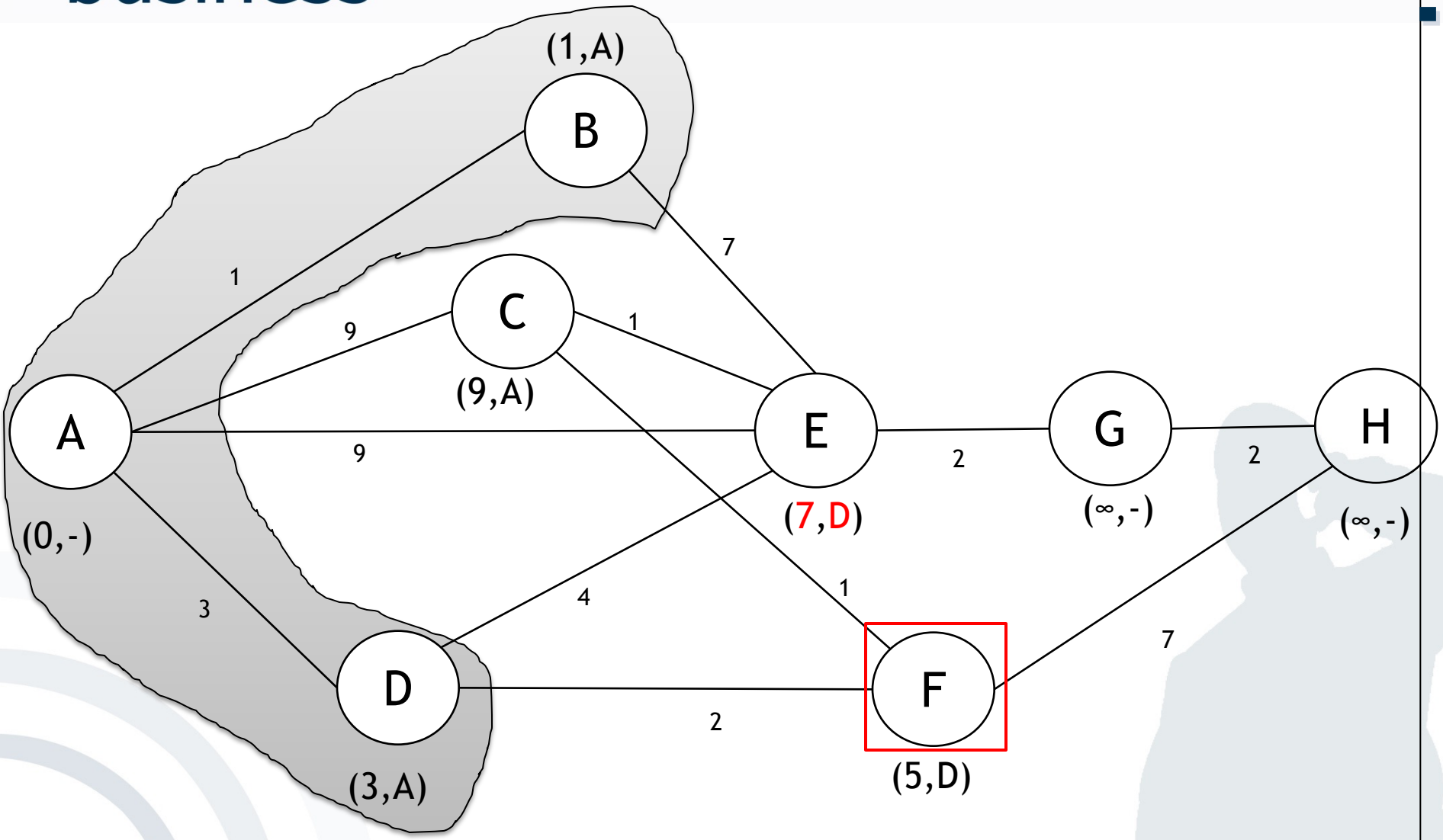
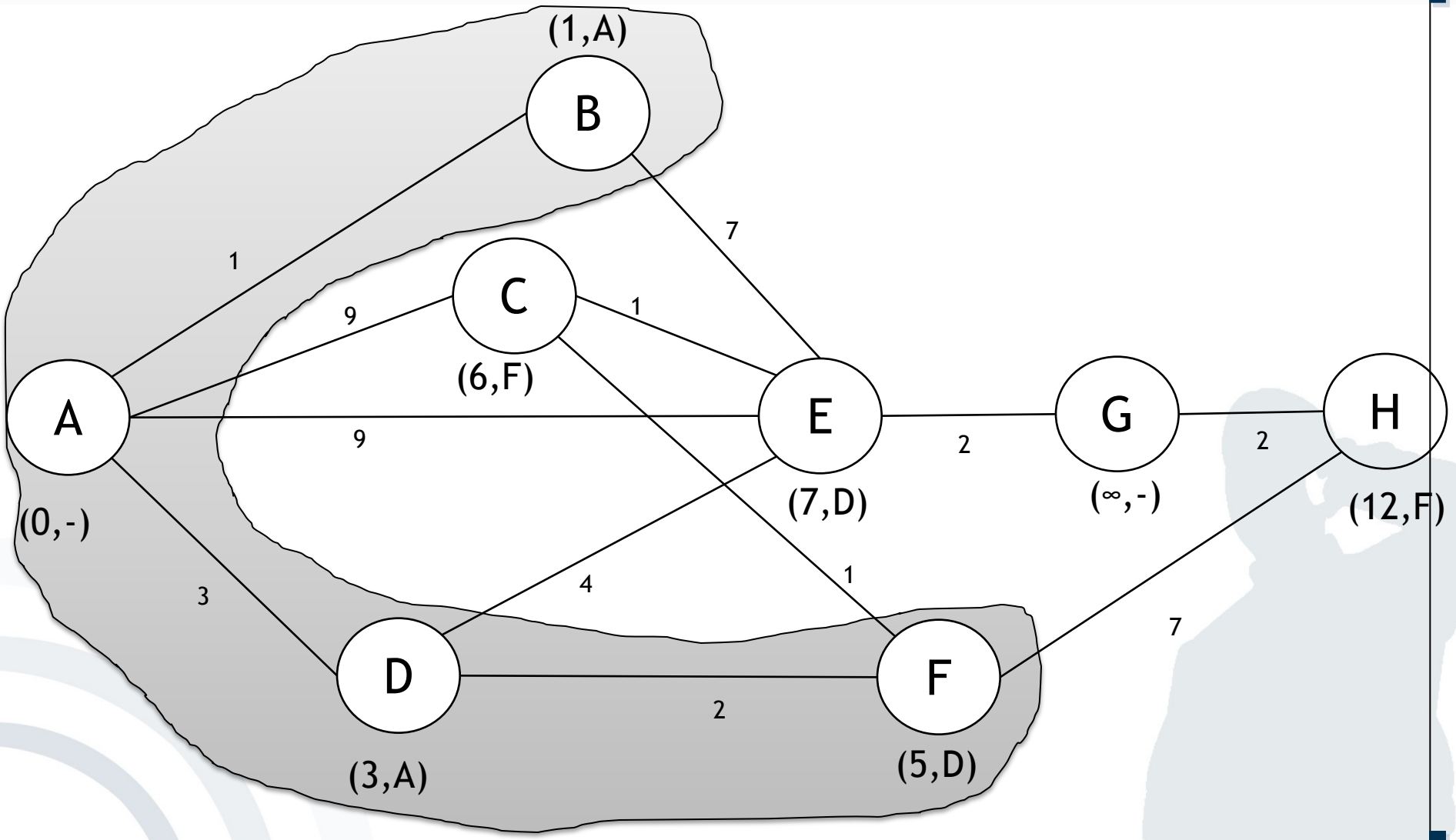
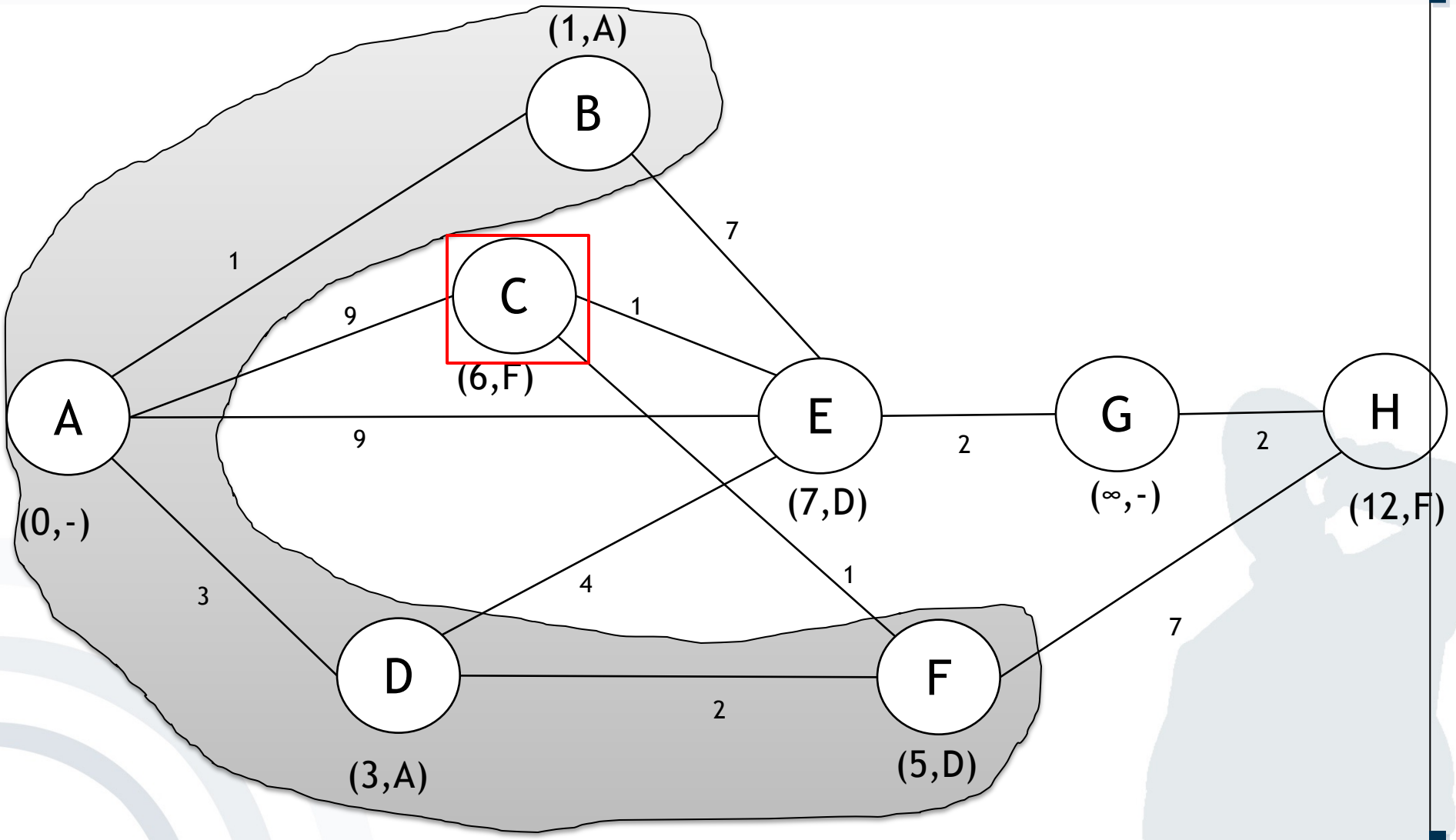


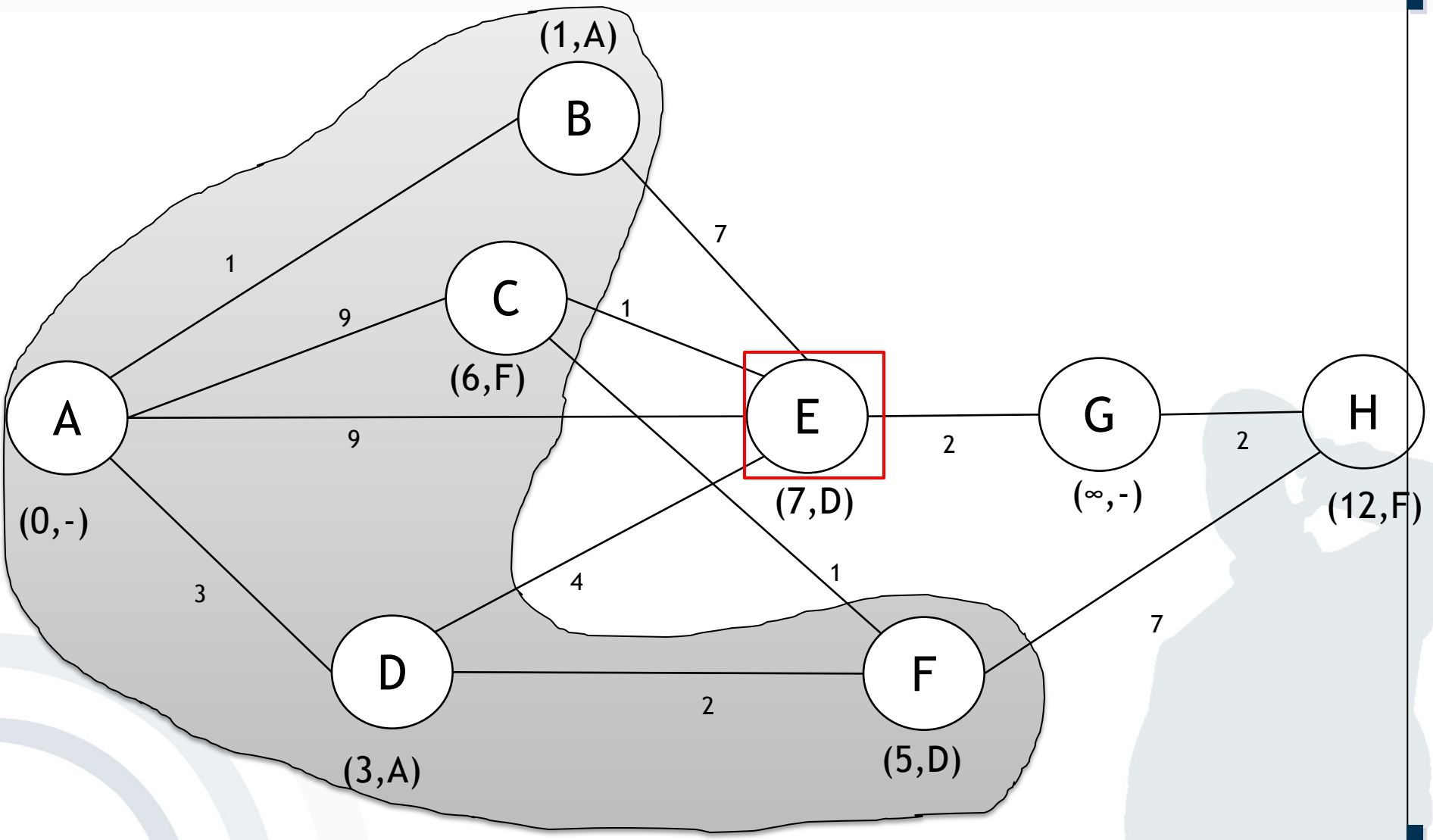
Exercise 3b): Solution



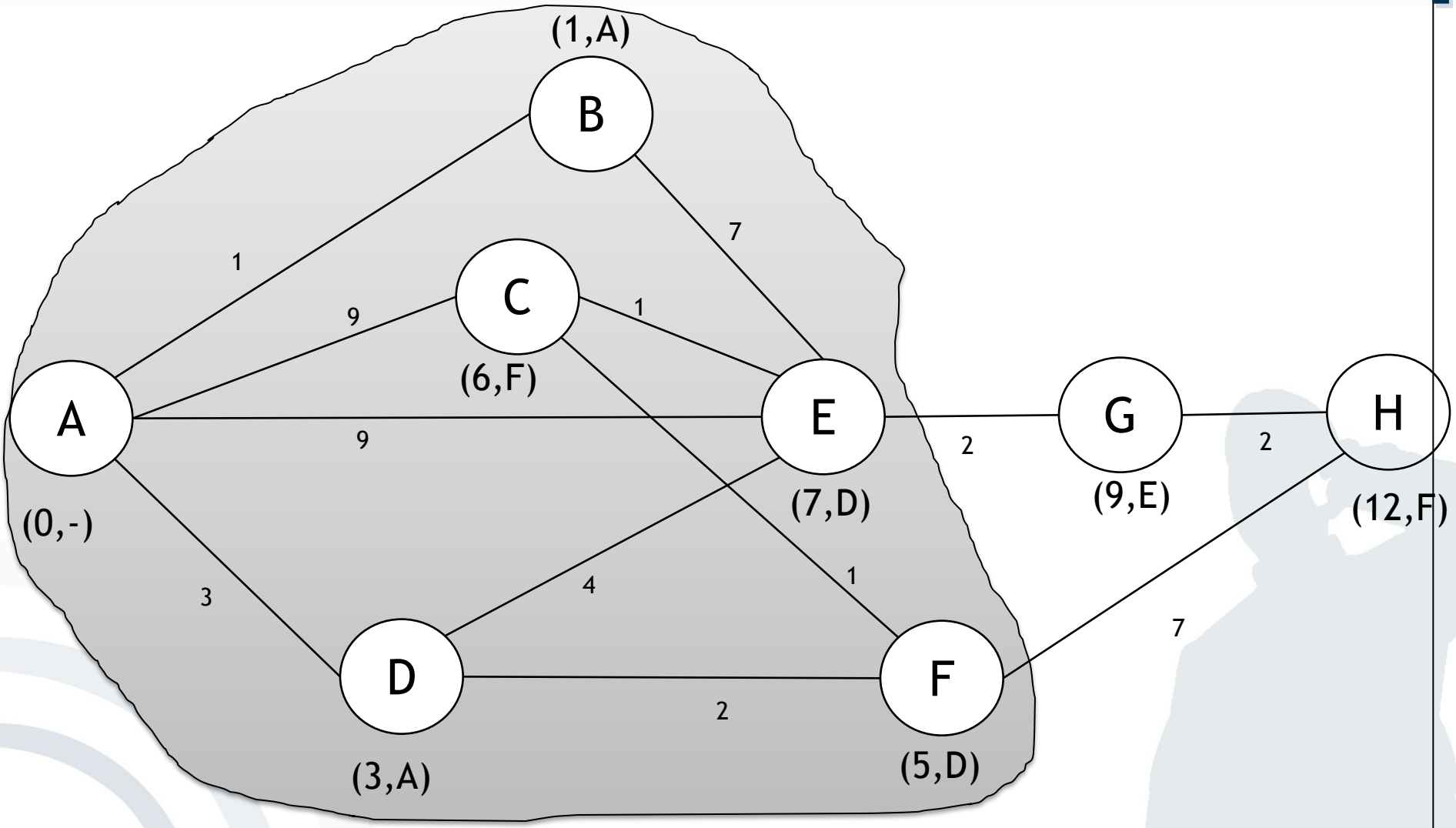
Exercise 3b): Solution



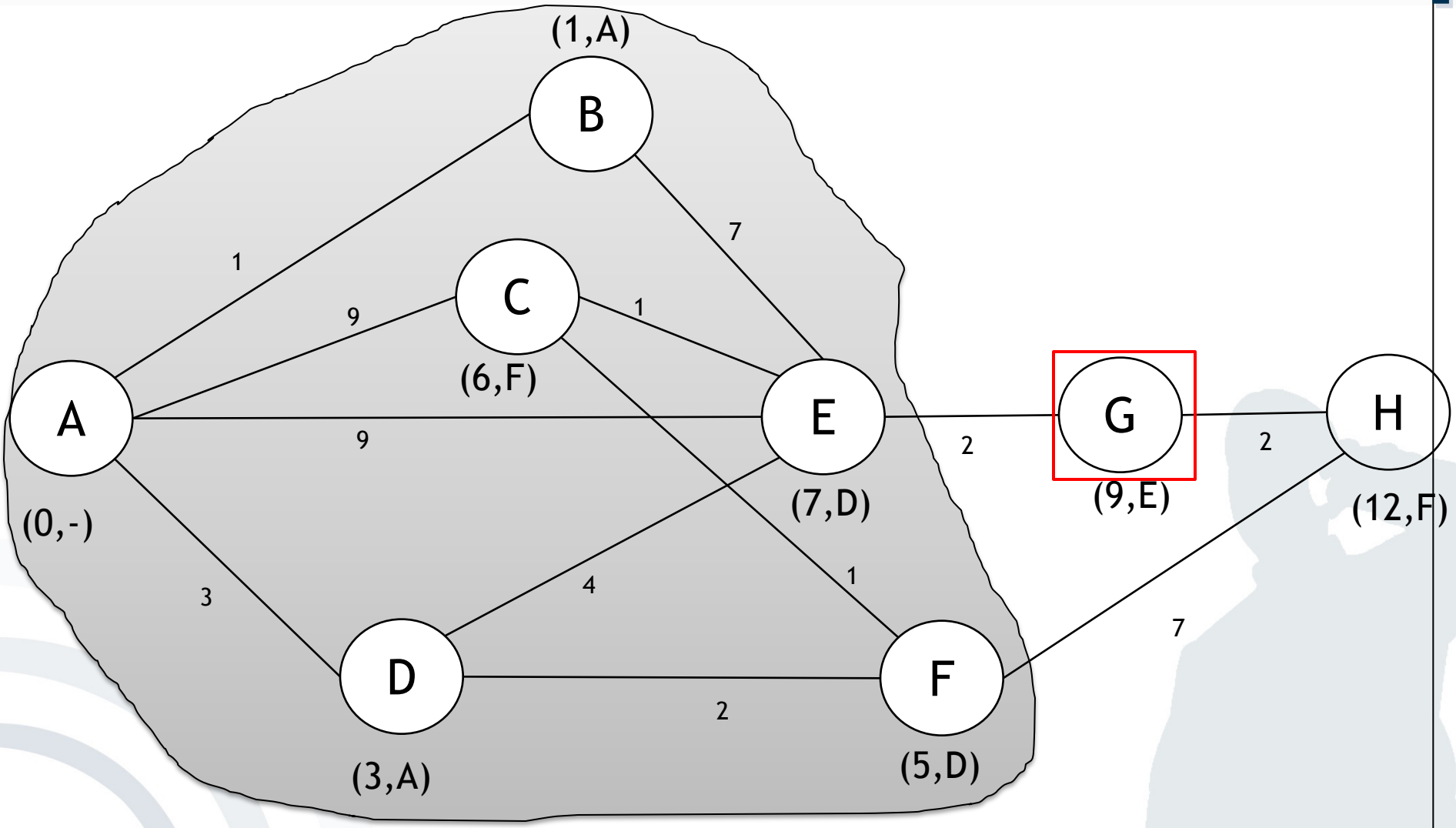
Exercise 3b): Solution



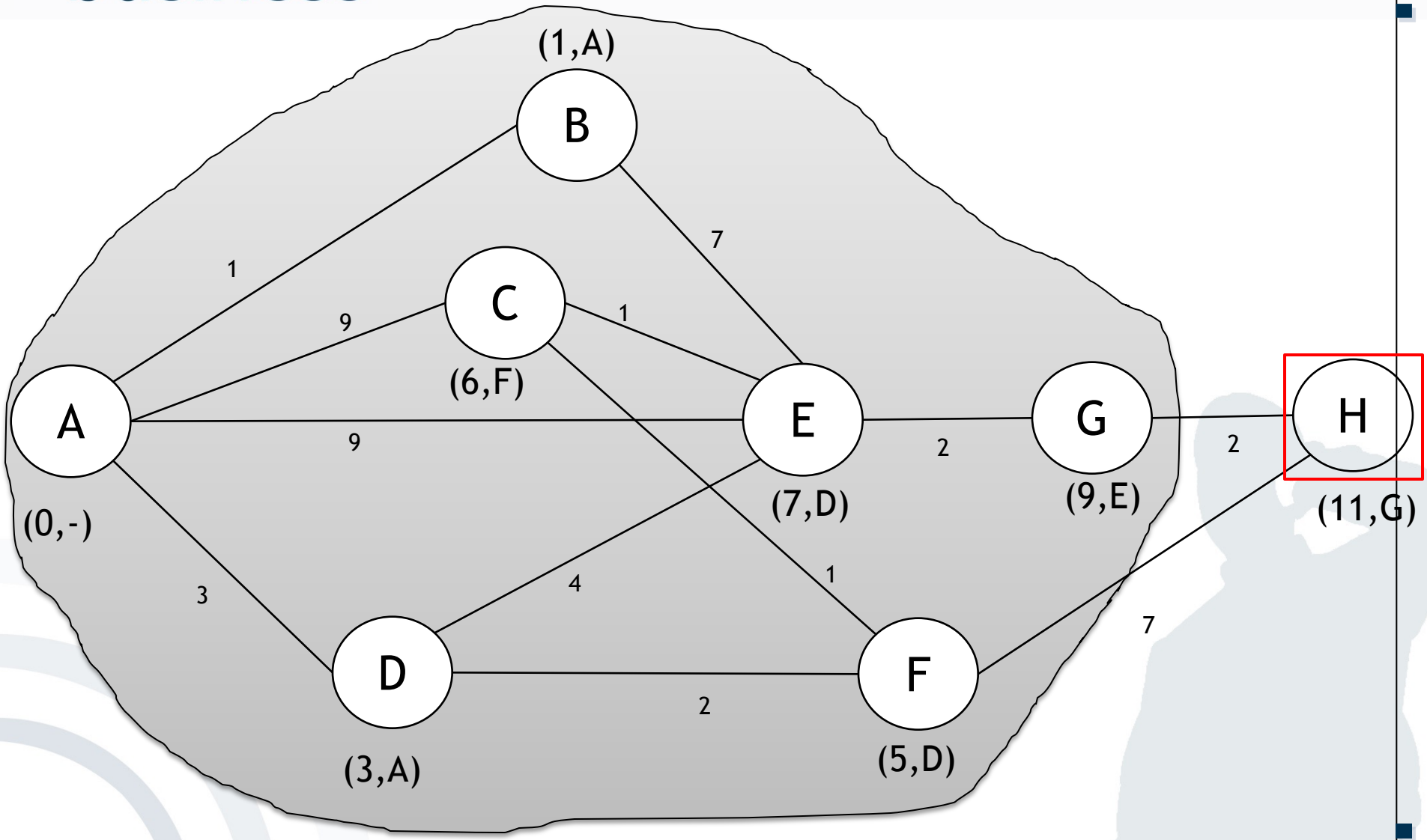
Exercise 3b): Solution



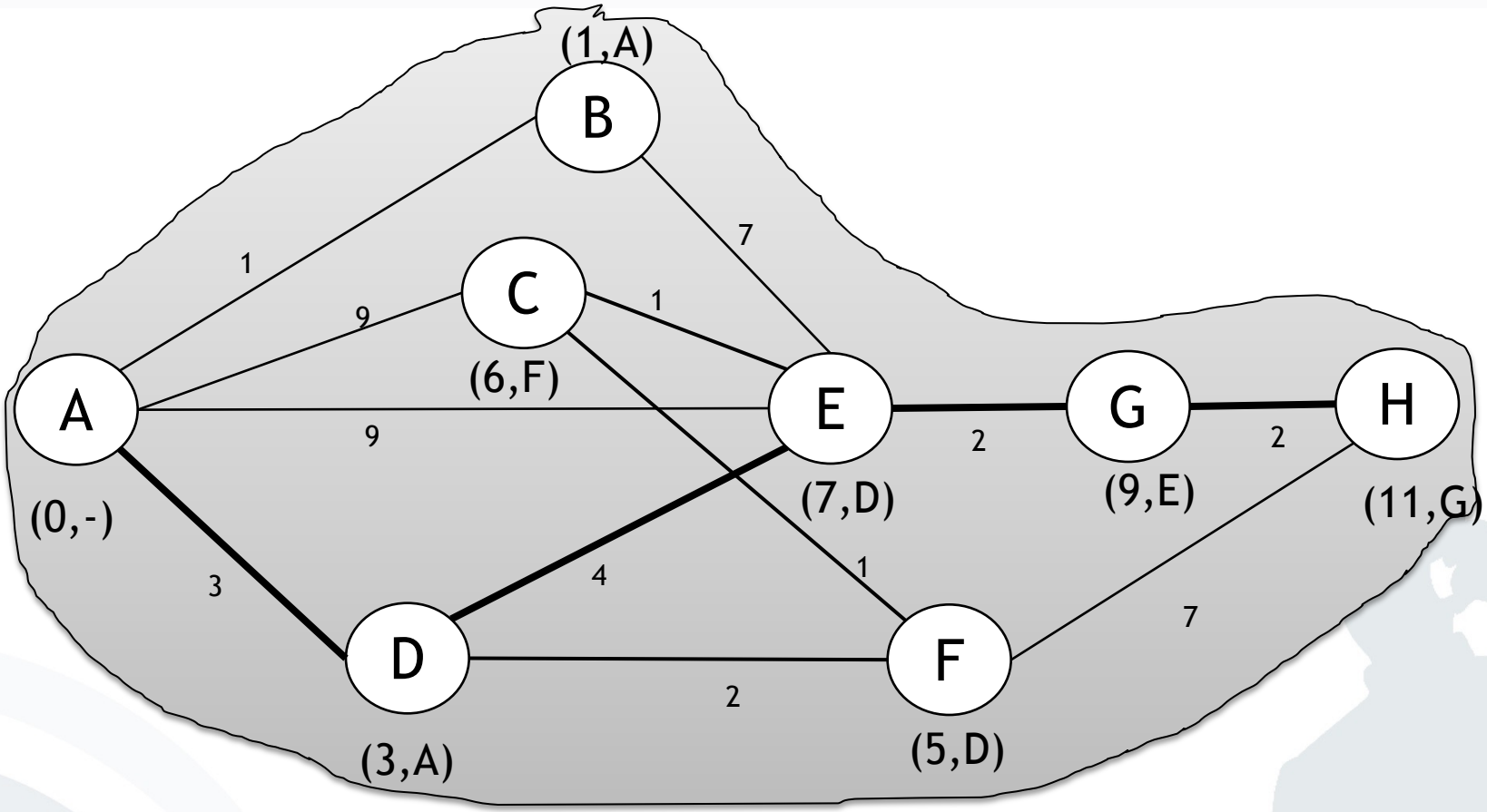
Exercise 3b): Solution



Exercise 3b): Solution

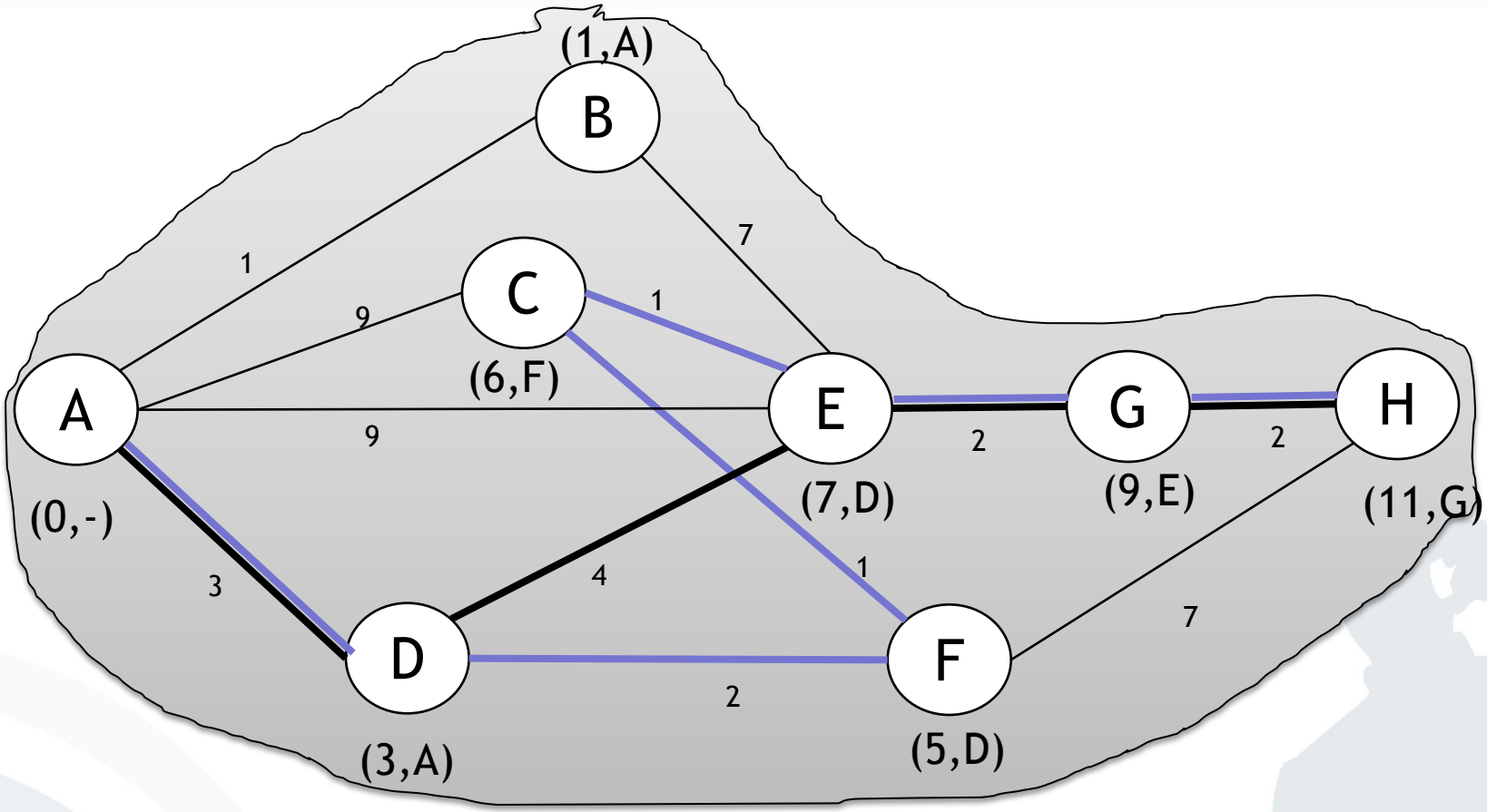


Exercise 3b): Solution



Shortest path: A → D → E → G → H

Exercise 3b): Solution



Shortest path: A → D → E → G → H

or: A → D → F → C → E → G → H

Agenda

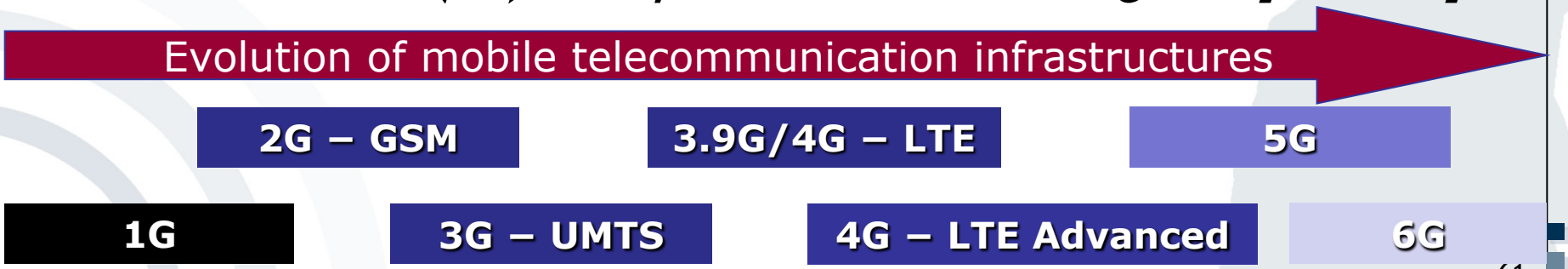
- Exercise 1: Layer-based Communication Models
- Exercise 2: OSI reference Model
- Exercise 3: Network Layer in OSI reference model
- Exercise 4: Wireless communication

Exercise 4: Wireless communication

a) Please name the main mobile voice and communication services (1G to 6G).

Mobile Telecommunication Infrastructures

- *1st Generation (1G) - Analogue networks*
- *2nd Generation (2G) - GSM networks*
  Global System for Mobile Communications
- *3rd Generation (3G/3.5G) - UMTS/HSPA/HSPA+*
  Universal Mobile Telecommunications System
  High Speed Packet Access / Evolved HSPA = HSPA+
- *3.9G or 4G - LTE*
  Long Term Evolution
- *4th Generation (4G) - LTE Advanced*
- *5th Generation (5G) - Mobile broadband*
- *6th Generation (6G) - Ubiquitous wireless intelligence [Latva19]*

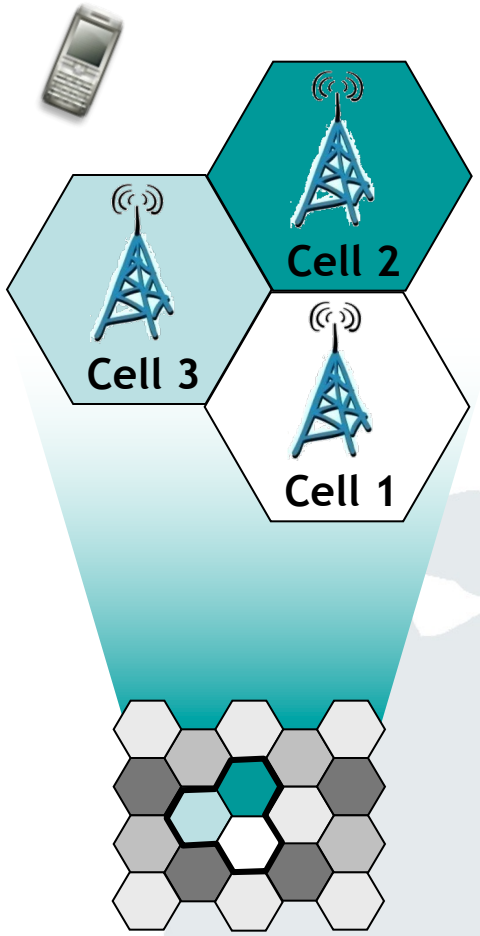


Exercise 4: Wireless communication

b) Please describe how cell-based communication works. What are advantages? What are disadvantages?

Exercise 4b): Solution

- Cellular networks are radio networks consisting of several transmitters.
- Each transmitter or base station, covers a certain area ➲ ***a cell.***
- Cell radii can vary from tens of meters to several kilometres.
- The shape of a cell is influenced by the environment (buildings, etc.) and usually neither hexagonal nor a perfect circle, even though this is the usual way of drawing them.



[Schiller2003]

Exercise 4b): Solution

- Cellular networks offer a number of advantages compared to centralised radio systems:
  - ***Higher capacity:*** Cells offer the possibility to "*reuse*" the transmission frequencies assigned to mobile devices (e.g. by multiplexing). In order to do so, the networks need a thorough planning of the position of base stations and their frequencies.
    - ➲ More users can use the infrastructure
  - ***Reduced transmission power:*** Reduced power usage for the mobile device, due to the fact that only a limited amount of transmission power is needed in a small cell, compared to a far away base station.
    - ➲ Reduced power consumption for mobile devices

Exercise 4b): Solution

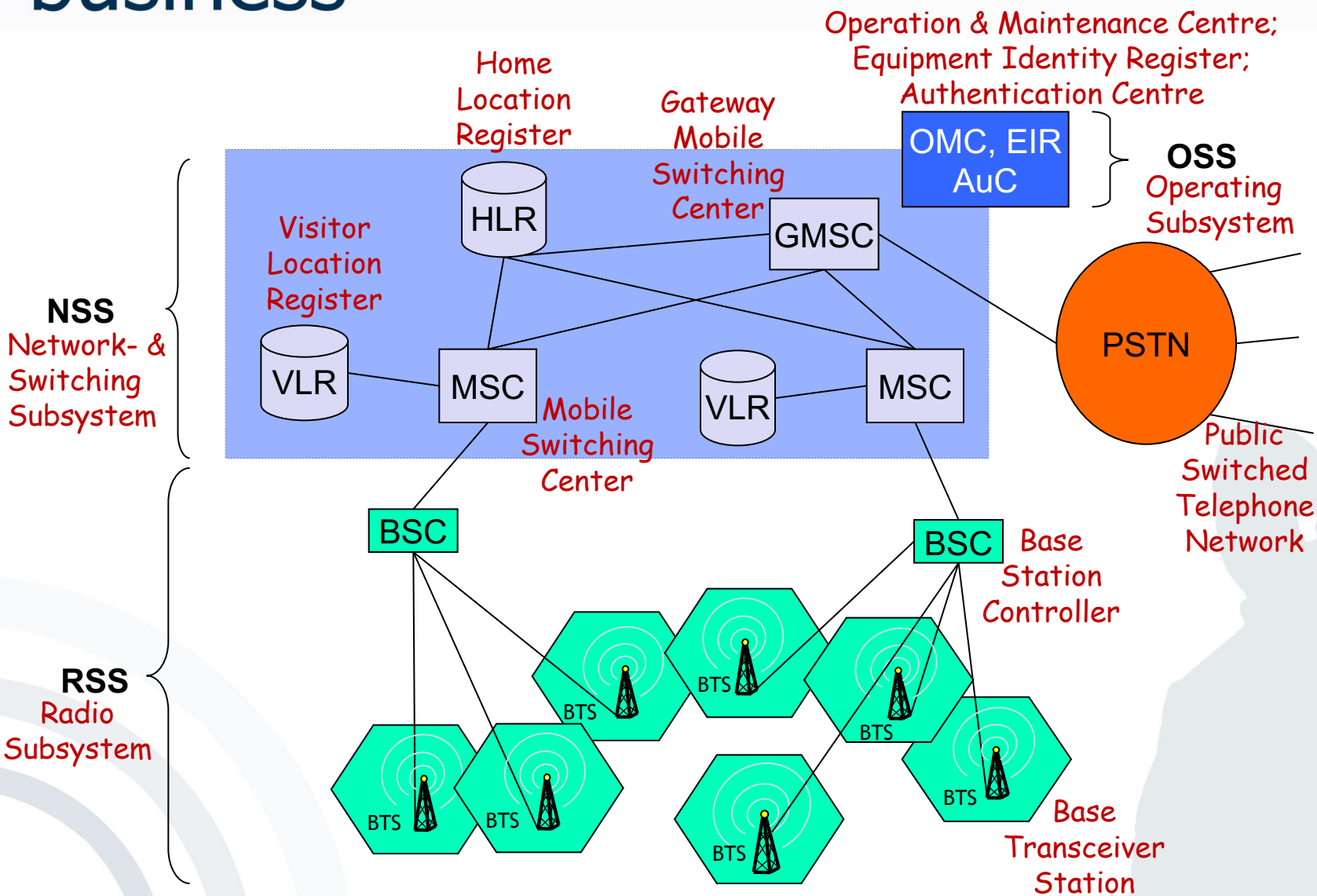
- Cellular networks offer a number of advantages compared to centralised radio systems:
  - ***Robustness:*** Cellular systems are decentralised with regard to their base stations. In the case that one antenna fails, only a small area gets affected.
    - ➲ Failure of one base station does not affect the complete infrastructure
  - ***Better coverage:*** Cells can be adapted to geographic conditions (mountains, buildings, etc.).
    - ➲ Better availability of the infrastructure

But: A complex and costly infrastructure is required, in order to link all base stations. This includes switches, antennas, location registers, etc.

Exercise 4: Wireless communication

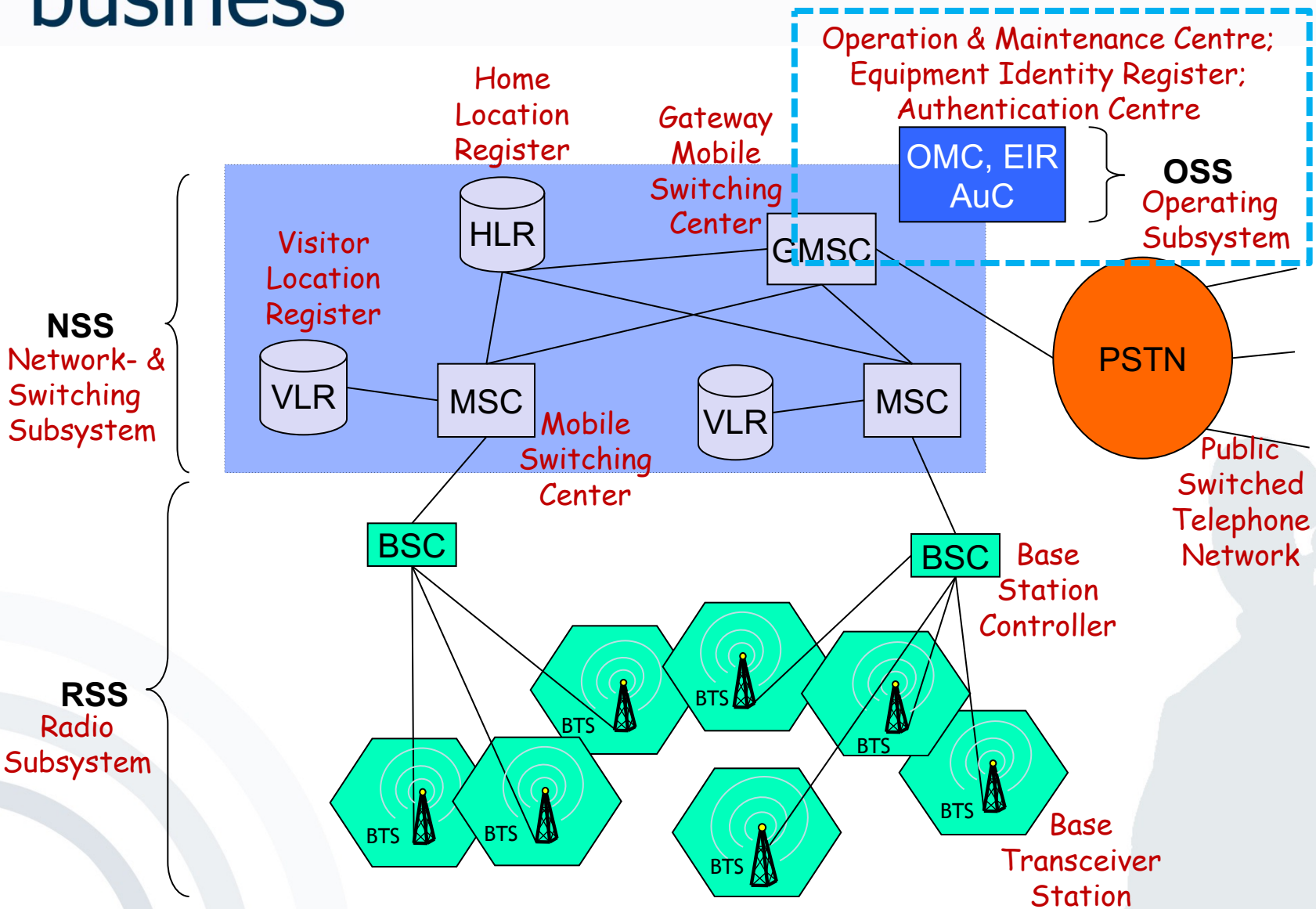
c) GSM is one example of communication services relying on cell-based communication. Please explain the main components.

Exercise 4c): Solution



Based on [Schiller2003]

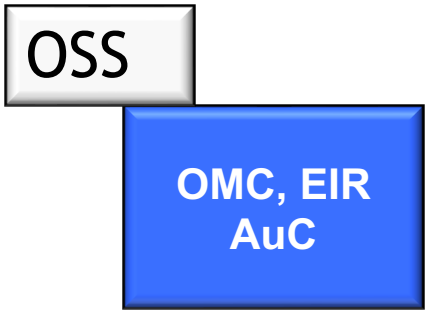
Exercise 4c): Solution



Based on [Schiller2003]

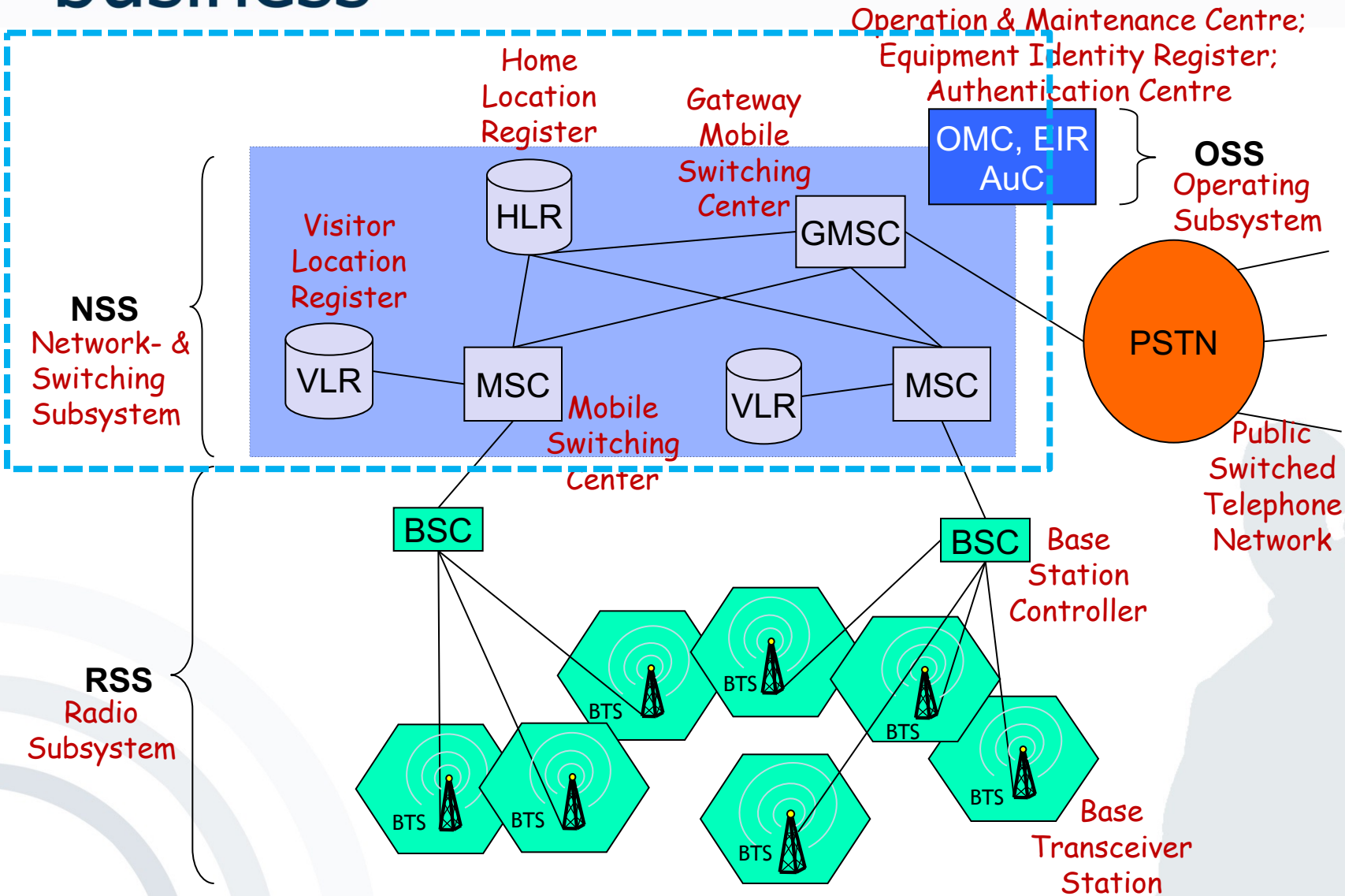
GSM – Operation Subsystem (OSS)

- **Operation Subsystem (OSS)**
  - Supervises operation and maintenance of the whole GSM network



- Components:
  - **Operation and Maintenance Centre (OMC):** Supervises each network component and creates status reports
  - **Authentication Centre (AuC):** Protects identity of participants & data transmission, administrates keys
  - **Equipment Identity Register (EIR):** Database with identification list for devices, e.g. stolen terminals (whitelist, greylist, blacklist)

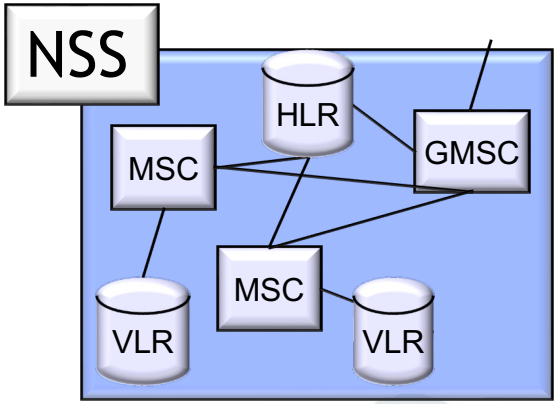
Exercise 4c): Solution



Based on [Schiller2003]

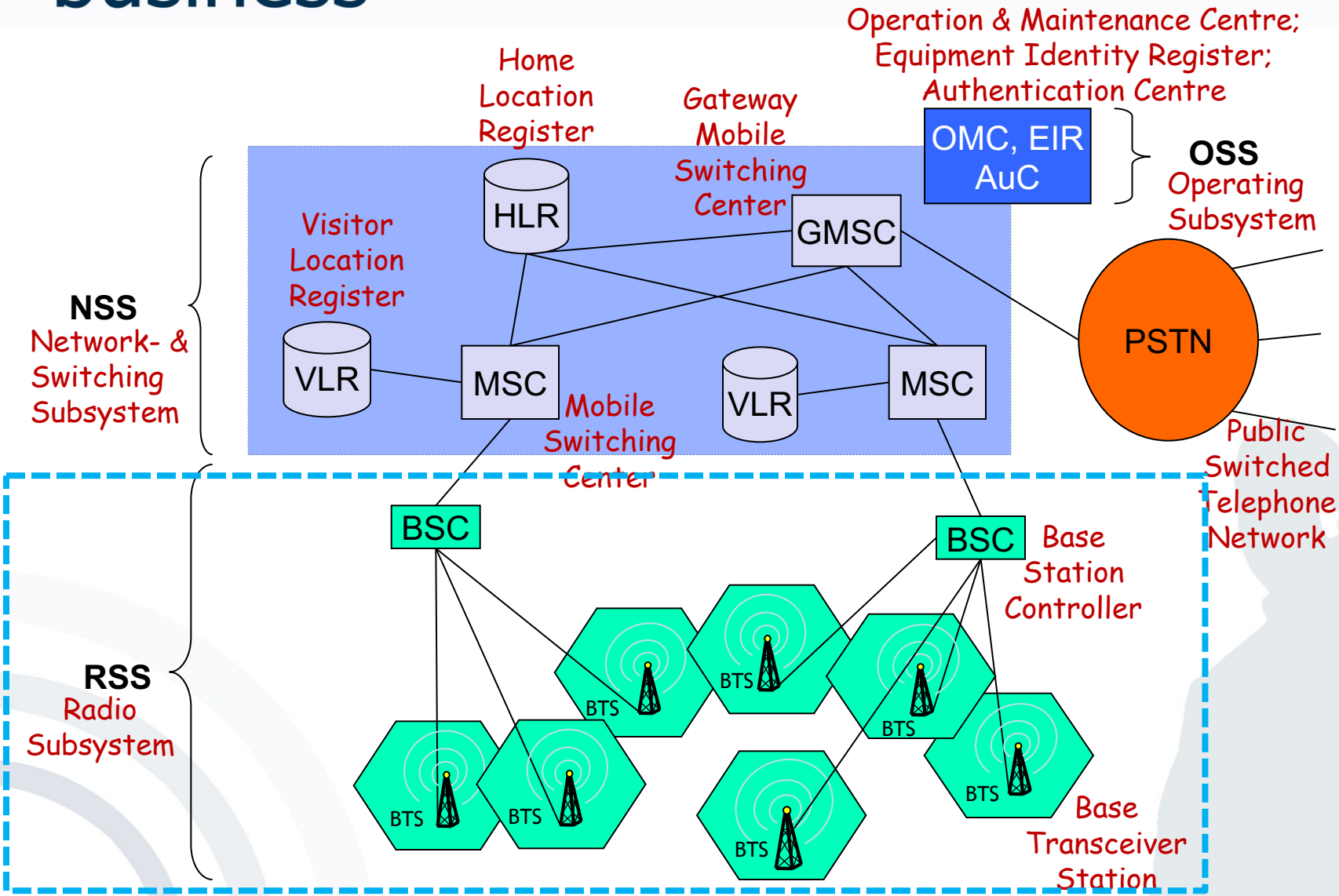
GSM – Network & Switching Subsystem (NSS)

- **Network & Switching Subsystem (NSS)**
  - Connects radio network with conventional networks
  - Locates subscribers and monitors change of location



- Components:
  - **Mobile Switching Centre (MSC):** Switching center for initiation, termination and handover of connections
  - **Home Location Register (HLR):** Central database with subscribers' data (telephone numbers, keys, locations)
  - **Visitor Location Register (VLR):** Database assigned to every MSC with subscribers' data (HLR fraction copy) of active subscribers in the MSC's range
  - **Gateway Mobile Switching Center (GMSC):** Terminates the PSTN (Public Switched Telephone Network) signaling and traffic formats and converts this to protocols employed in mobile networks

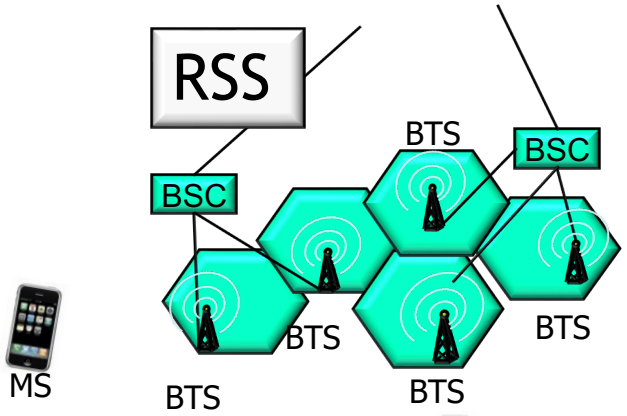
Exercise 4c): Solution



Based on [Schiller2003]

GSM – Radio Subsystem (RSS)

- **Radio Subsystem (RSS)**
  - System consisting of radio
  - Specific components

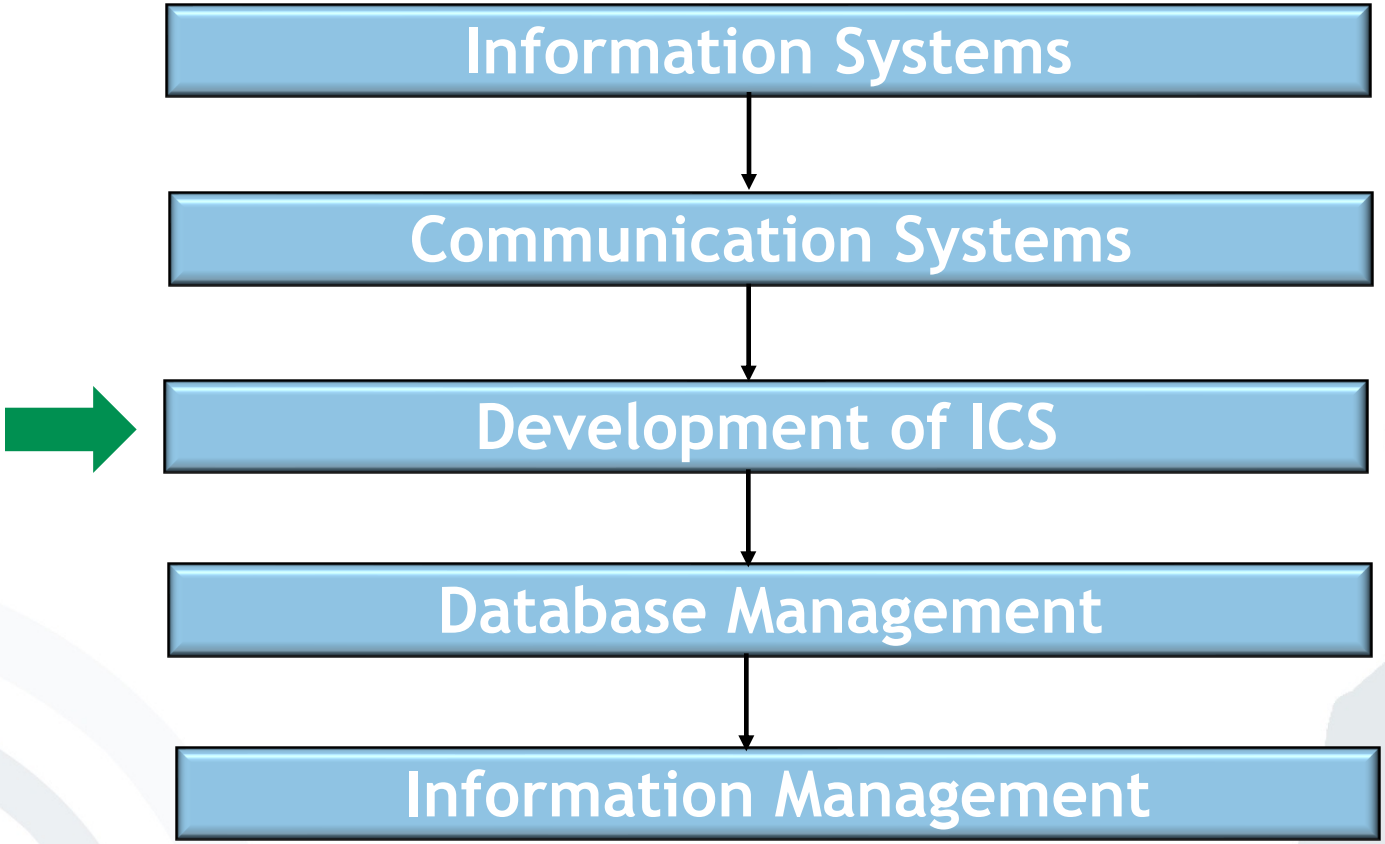


- Components:
  - **Mobile Station (MS):** System of mobile terminal & SIM
  - **Base Transceiver Station (BTS):** Radio facility for signal transfer. A BTS serves one GSM cell (~100m to ~30km radius).
  - **Base Station Controller (BSC):** Administrates affiliated BTS and supervises e.g. frequency allocation and connection handover between cells.

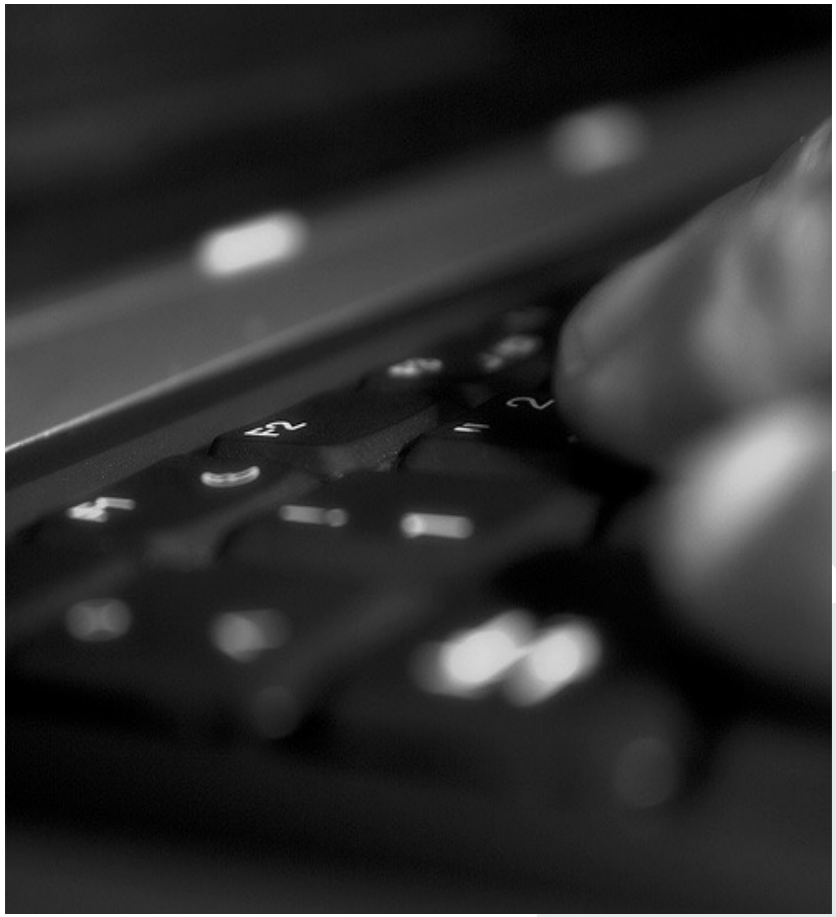
Components of the Course

- Introduction to layer-based Communications ✔
- Fixed Networks (✔)
- Wireless Networks ✔

Next exercise



Thank you!



Jenser (Flickr.com)