18-452/18-750
Wireless Networks and Applications
Lecture 1: Course Organization and Overview

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http://www.cs.cmu.edu/~prs/wirelessS18/

Outline

- **Goals and structure of the course**
- **Administrative stuff**
- **A bit of history**
- **Wireless technologies**
- **Building a network**

- **Please ask questions!**

Goals of the Course

- **Learn about the unique challenges in wireless networking**
  - » Starting point is "regular" wired networks
  - » But the physical layer is very different!
- **Gain an understanding of wireless technologies at the physical, MAC, and higher layers**
  - » Physical layer essentials for computer systems types
  - » Focus of course is on the wireless protocol layer
  - » Implications for the higher layers of the protocol stack
- **Get some hands-on experience in working with wireless networks and devices**
  - » Measurements of a wireless network
  - » Implementing wireless protocols, algorithms

Lectures

- **Introduction**
  - » Why are wireless networks so interesting?
  - » A very quick overview of networking
- **Physical layer concepts (~5)**
  - » Narrow focus: understanding the impact on higher layers
  - » Not an in-depth course on the communications field!
- **LANs and WiFi (~6)**
- **Cellular networks (~3)**
- **Other technologies; PAN, RFID, NFC, …. (~5)**
- **GPS, localization, sensing (~3)**
- **Deployments: sensor networks, ad hoc, …**

Projects

Projects are hands-on, team-based

1. **Measurement project to improve your understanding of wireless link properties**
   - » **Measure signal strength and other signal properties**
   - » **How do they relate to the physical context?**
2. **Design, implement and evaluate some wireless protocol, algorithm or system**
   - » **Needs to deal with the unpredictable nature of wireless links and with mobility**
   - » **Multi-phase projects: start small and work your way up to larger networks**
   - » **Define your own project or set project**

Survey Presentations

- **Present a survey of a particular wireless topic to the class**
- **Done in small teams or solo**
- **Survey is based on research papers**
  - » **Pick from a list of topics or define your own topic**
  - » **Initial set of papers provided for the list**
- **Goals are:**
  - » **Learn about a specific topic in depth**
  - » **Develop critical thinking skills**
  - » **Improve your presentation skills**

Graduate versus Undergraduate Course Numbers

The course content is the same, but they are separate courses:

- **Some different questions on the tests**
- **Different levels of expectation for projects and surveys**
  - » **E.g., original versus set project**
- **Final grades are assigned as separate pools**
- **The expectation is that students sign up for the course number that matches their status**
  - » **Talk to the instructor if you want to sign up for the "wrong" course number, e.g., ECE IMB students**
- **18-452 is a Software Systems area course**

Prerequisites

- **The course assumes you have taken an "Introduction to Computer Systems" course**
  - » **For example based on the O'Hallaron and Bryant book**
- **We will also build on basic networking and signals concepts but the course includes introductory material on these topics**
- **Programming experience needed for project**
  - » **Often: C/C++ or other language, depending on project**
- **Course should be accessible to students with a broad range of backgrounds, but …**
- **I don't know you, so please ask questions when something is not clear!**

More Specifically ...

- **For undergraduates – 18-452**
  - » **18-213 or 15-213: Introduction to Computer Systems**

- **For graduates – 18-750**
  - » **15-513/18-600 or …**
  - » **Equivalent: a basic understanding of how computer systems work both inside the box (CMU, memory, IO, ..) and across boxes (familiarity with communication)**
  - » **If you have a degree in computer science or computer engineering, you should generally be ok**
  - » **Talk to me if you have concerns**

Grading

Grade distribution:
- **Homeworks: 10%**
- **Project 1: 5%**
- **Project 2: 25%**
- **Survey: 10%**
- **Midterm: 20%**
- **Final: 30%**

Administrative Stuff

- **Textbook" "Wireless Communication Networks and Systems", Corry Beard and William Stallings, Pearson, 2015**
  - » **Best fit for the course**
- **The course is <u>not</u> based on the book**
  - » **The book should be used to read about the topics covered in class, e.g., to clarify points or get more depth**
  - » **Book does not cover all material, but slides are detailed**
- **Web page is primary source for information**
  - » **Lecture material**
  - » **Office hours, contact information, …**
  - » **Dates for quizzes, exams and project deadlines**
- **We will use Canvas for assignments**

More Administrative Stuff

- **Lectures are Mo/We 2:30-4:20**
  - » **But lectures will typically be 80 minutes**
  - » **May go longer, e.g., to make up time for travel**
- **Recitations are Fr 10:30-11:50**
  - » **Recitations will be used for the project**
  - » **There will relatively few recitations, but**
  - » **May use recitation slot for make up lectures**
- **Course admin is Ms. Malloy – Gates 9006**
  - » **Pick up assignments, make appointment, …**
- **Teaching assistant: Matthew McCormack**

Collaboration

- **Traditional rules of collaboration apply**
    - » **https://www.cmu.edu/policies/student-and-student-life/academic-integrity.html**
- **You must complete individual assignments and tests by yourself**
- **You are expected to collaborate with your partner in the team-based projects**
- **It is acceptable and encouraged to help fellow students with generic problems**
    - » **E.g. where to find documentation, use of tools, ..**
- **You must give proper credit when reusing material**
    - » **But check with the instructors first**

Course Material

- **Most slides were prepared by the course instructor**
- **Some slides contain material from other sources**
    - » **Previous co-instructors have contributed slides**
    - » **Some figures are taken from the textbook**
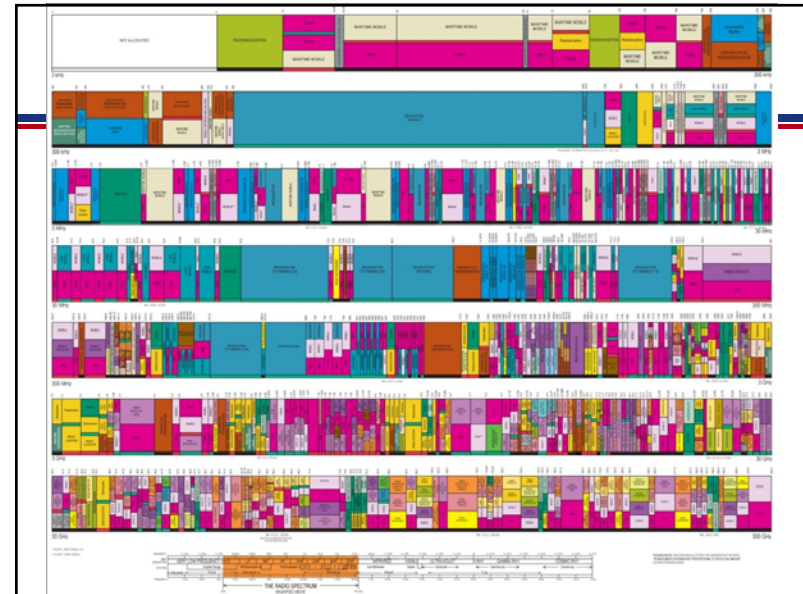   - » **Some lectures contain material from other sources**

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Spectrum Shared by Many Users

- **Spectrum allocated by FCC and NTIA**
- **Two types of spectrum bands:**
  1. **Licensed spectrum: exclusive access to an organization**
     - **Federal agencies, broadcast TV, first responders, …**
     - **Commercial, e.g., cellular operators**
  2. **Unlicensed spectrum: everyone can use it with appropriate equipment, e.g., WiFi, zigbee, …**
- **Other trends:**
  » **Technology improvements have allowed us to use higher frequency bands over time**
  » **Many bands have low utilization**
  » **Older bands often use very inefficient technologies**

Wireless Technologies
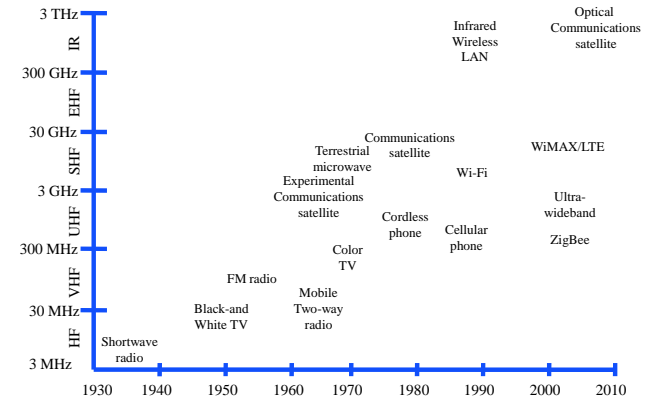
Why so many Technologies?

- **Diverse application requirements**
  » **Energy consumption**
  » **Range**
  » **Bandwidth**
  » **Mobility**
  » **Cost**
- **Diverse deployments**
  » **Licensed versus unlicensed**
  » **Provisioned or not**

- **Technologies have different**
  » **Signal penetration**
  » **Frequency use**
  » **Cost**
  » **Market size**
  » **Age, integration**
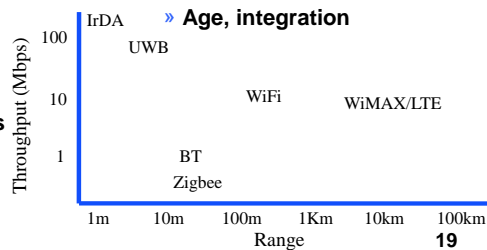
Application Trends in Wireless

- **Early days: specialized applications**
  » **Broadcast TV and radio, voice calls, data, ..**
  » **Holds for wireless and wired**
- **Today: flexible wireless platforms**
  » **Phones, tables, and laptops all run similar applications**
  » **Same trend as for wired networks: the internet took over**
- **Wireless is expanding in new domains**
  » **Sensor networks, body area networks, …**
  » **Edge of the internet is increasingly wireless**
  » **Many of these applications are unique to wireless**
- **Future?**

Scope of Wireless Covered in the Course

- **Significant depth on two technologies:**
  - » **Wireless in unlicensed band: WiFi**
  - » **Wireless in licensed spectrum: cellular**
  - » **Focus is on optimizing performance with limited spectrum**
  - » **Sophisticated protocols to fight challenging physical layer**
- **Other wireless communication technologies**
  - » **RFID/NFC, low-power, satellite, UWB, visible light, …**
- **Localization and sensing**
  - » **GPS, Wifi for localization and sensing, …**
- **Wireless deployments**
  - » **Infrastructure WiFi, ad hoc, sensor networks, vehicular, DTN, visible light, ..**
 - » **Some topics covered in the surveys**

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Some History…

- **Tesla credited with first radio communication in 1893**
- **Wireless telegraph invented by Guglielmo Marconi in 1896**
- **First telegraphic signal traveled across the Atlantic ocean in 1901**
- **First "cell phone" concept developed in 1946**
  - » **But only voice – data took another 50+ years**
- **GPS project started in 1973, complete in 1995**
- **WiFi technology developed in the mid-1990s**

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  - » **What pieces do we need**
  - » **The OSI model**
  - » **Packet-based communication**
  - » **Challenges in Wireless Networking**

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The Internet is Big and Has Many, Many Pieces

How do you design something this complex?

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What Pieces Do We Need?

Module:
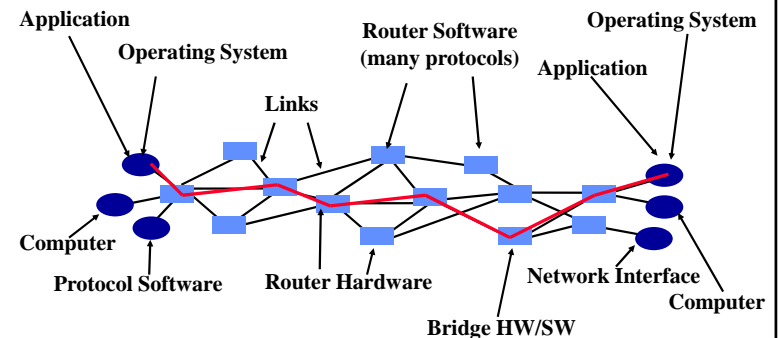
- **We need to be able to send bits**
  - » Over wired and wireless links
  - » Based on analog signals

  Physical

- **We really want to send packets**
  - » Statistical multiplexing: users can share link
  - » Need addresses to deliver packets correctly

  Datalink Network

- **But network may not be reliable**
  - » Bit errors, lost packets, …
  - » Must recover from these errors end-to-end

  Transport

- **You need applications and services**
  - » Otherwise: who cares?

  Application

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Hosts Exchanging Packets can be Easy or Hard

Scaling up

- **Two or more hosts talk over a wire (bits)** — Physical
- **Groups of hosts can talk at two levels** — Physical
  - » Hosts talk in a network is homogeneous in terms of administration and technology — Datalink
  - » Hosts talk across networks that have different administrators and technologies — Internet
- **Differ in physical and admin properties, scale**

Internet
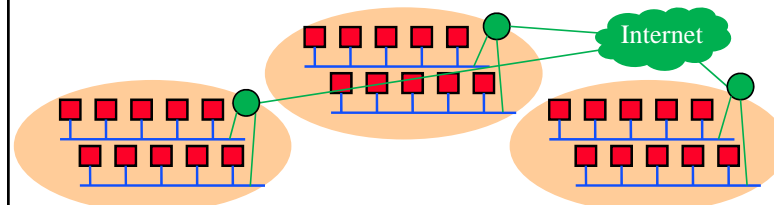
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A Bit More Detail

Scaling up the network

- **Physical layer delivers bits between the two endpoints of a "link"**
  - » Copper, fiber, wireless, visible light, …
- **Datalink layer delivers packets between two hosts in a local area network**
  - » Ethernet, WiFi, cellular, …
  - » Best effort service: should expect a modest loss rate
  - » "Boxes" that connect links are called bridges or switches
- **Network layer connects multiple networks**
  - » The Inter-net protocol (IP)
  - » Also offers best effort service
  - » Boxes that forward packets are called routers

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Our Internet So Far

Application

Transport

Inter-network

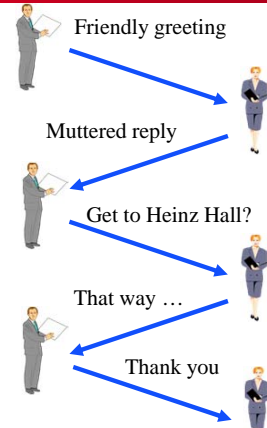**Datalink**

Physical

- **The Internet as five modules that are stacked as a set of layers**
  - » More on this later
- **Five layers is nice, but …**
  - » Each module is still huge!
  - » What about communication?
- **We need protocols!**
- **Protocol modules within each layer on different devices allow the devices communicate**

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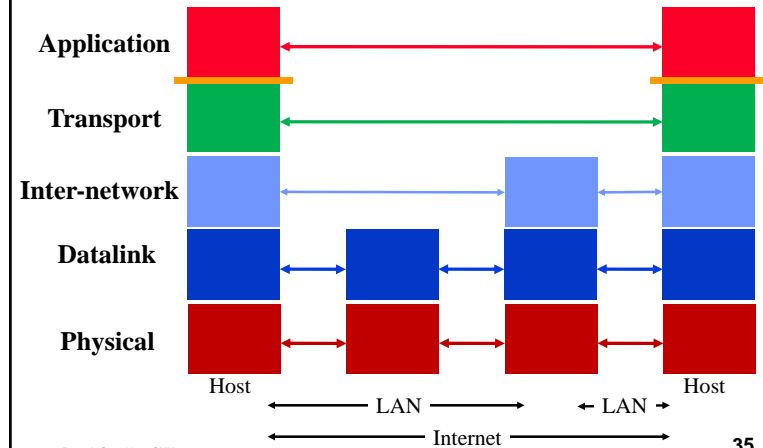
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Protocol Enable Communication

- **An agreement between parties on how communication should take place.**
- **Protocols must define many aspects of the communication.**
- **Syntax:**
  - » **Data encoding, language, etc.**
- **Semantics:**
  - » **Error handling, termination, ordering of requests, etc.**
- **Protocols at hardware, software, *all* levels!**
- **Example: Buying airline ticket by typing.**
- **Syntax: English, ascii, lines delimited by "\n"**

Friendly greeting

Muttered reply

Get to Heinz Hall?

That way …

Thank you

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Protocol and Service Levels

Application

Transport

Inter-network

Datalink

Physical

Host   Host

|← LAN →| ← LAN →

|← Internet →|

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The ISO Layered Network Model

The Open Systems Interconnection (OSI) Model.

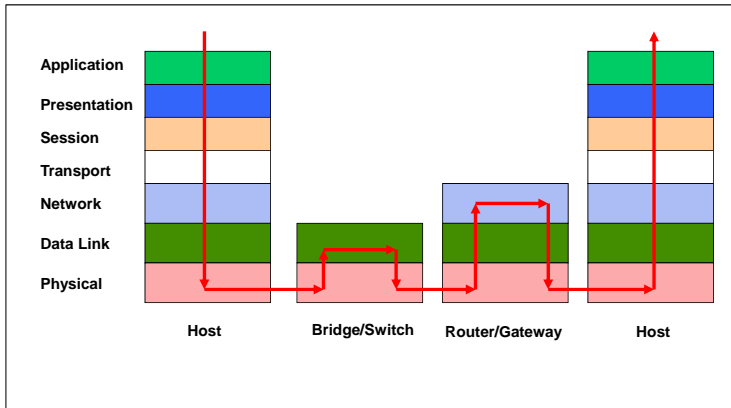|			
7	Application		Application
6	Presentation		Presentation
5	Session		Session
4	Transport		Transport
3	Network	Network	Network
2	Data link	Data link	Data link
1	Physical	Physical	Physical
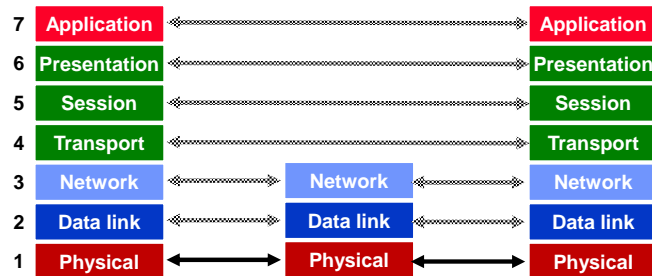
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OSI Functions

- **(1) Physical: transmission of a bit stream.**
- **(2) Data link: flow control, framing, error detection.**
- **(3) Network: switching and routing.**
- **(4) Transport: reliable end to end delivery.**
- **(5) Session: managing logical connections.**
- **(6) Presentation: data transformations.**
- **(7) Application: specific uses, e.g. mail, file transfer, telnet, network management.**
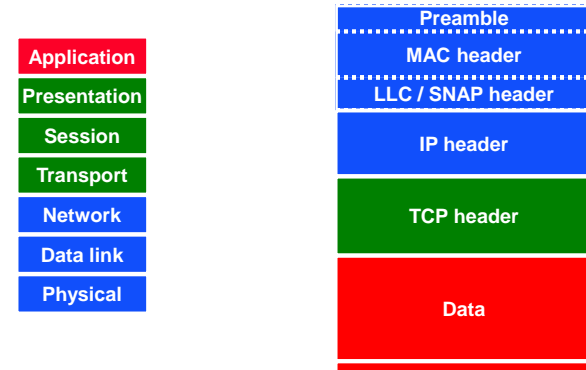
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Life of Packet

	Host	Bridge/Switch	Router/Gateway	Host
Application				
Presentation				
Session				
Transport				
Network				
Data Link				
Physical				

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A TCP / IP / 802.11 Packet

Application
Presentation
Session
Transport
Network
Data link
Physical

Preamble
MAC header
LLC / SNAP header
IP header
TCP header
Data

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Example: Sending a Web Page

Http hdr	Web page

TCP header   Application payload

Application
Presentation
Session
Transport
Network
Data link
Physical
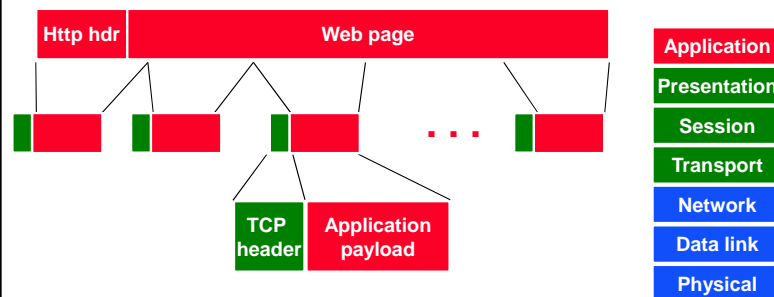
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OSI Motivation

- **Standard approach of breaking up a system in a set of components with well defined interfaces, but components are organized as a set of layers.**
  - » **Only horizontal and vertical communication**
  - » **Components/layers can be implemented and modified in isolation without affecting the other components**
- **Each layer offers a service to the higher layer, using the services of the lower layer.**
- **"Peer" layers on different systems communicate via a protocol.**
  - » **higher level protocols (e.g. TCP/IP, Appletalk) can run on multiple lower layers**
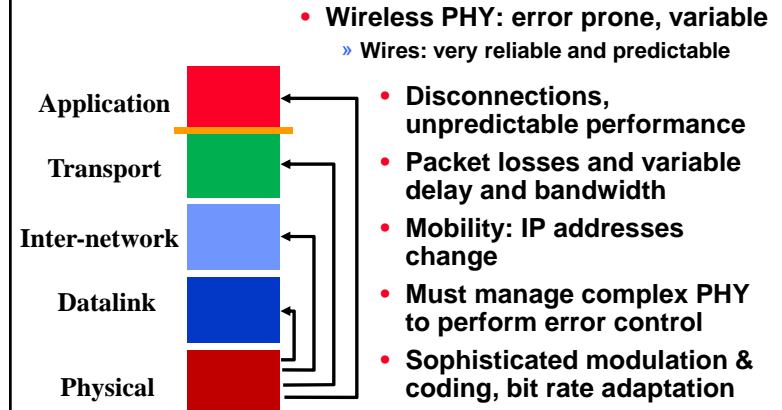 - » **multiple higher level protocols can share a single physical network**

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Benefits of Layered Architecture

- **Significantly reduces the complexity of building and maintaining the system.**
  - » **Effort is 7 x N instead of N^7 for N versions per layer**
- **The implementation of a layer can be replaced easily as long as its interfaces are respected** **True For Wireless?**
  - » **Does not impact the other components in the system**
  - » **Different implementation versus different protocols**
- **In practice: most significant evolution and diversity at the top and bottom:**
  - » **Applications: web, peer-to-peer, video streaming, ..**
  - » **Physical layers: optical, wireless, new types of copper**
  - » **Only the Internet Protocol in the "middle" layer**

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Impact of the Physical Layer

- **Wireless PHY: error prone, variable**
  - » **Wires: very reliable and predictable**

Application

Transport

Inter-network

Datalink

Physical

- **Disconnections, unpredictable performance**
- **Packet losses and variable delay and bandwidth**
- **Mobility: IP addresses change**
- **Must manage complex PHY to perform error control**
- **Sophisticated modulation & coding, bit rate adaptation**

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