# Class Meeting: Lectures 19 and 20, Wireless & Security

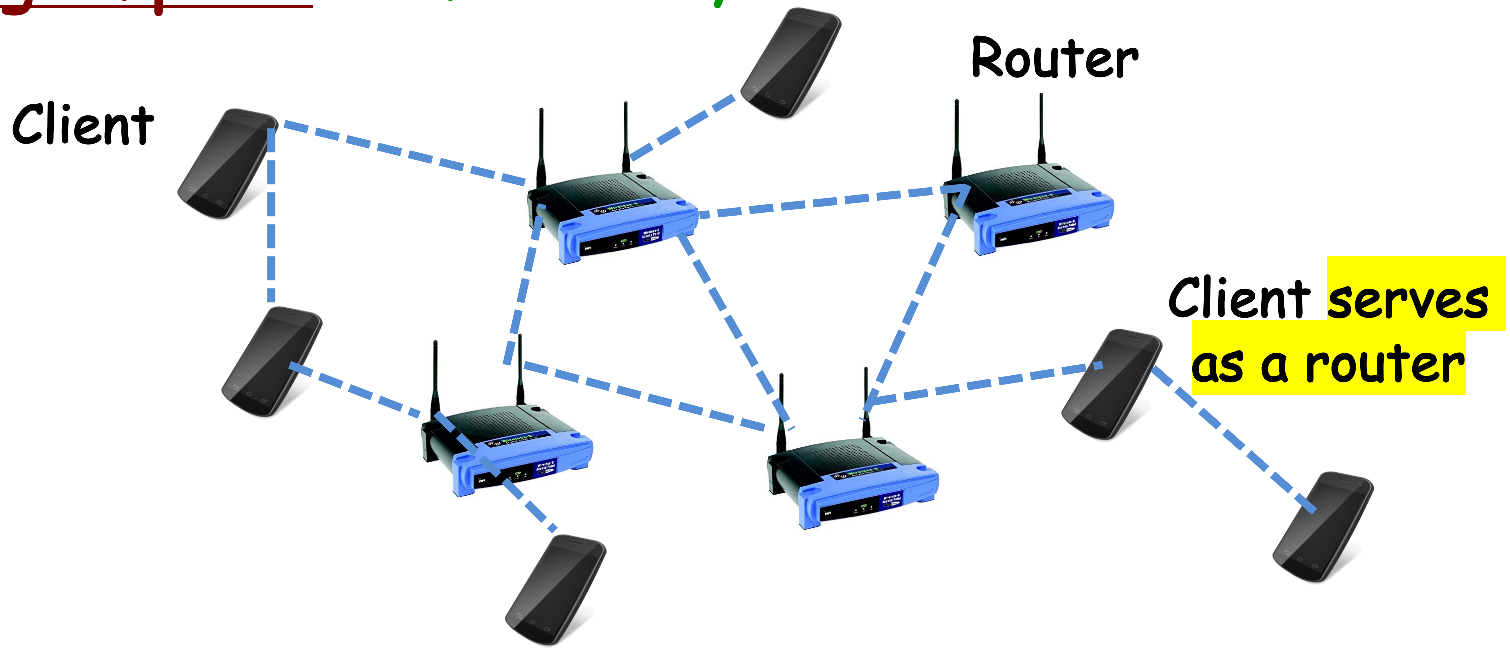
## COS 461: Computer Networks

Kyle Jamieson

[Selected parts adapted from S. Shenker, UC Berkeley]

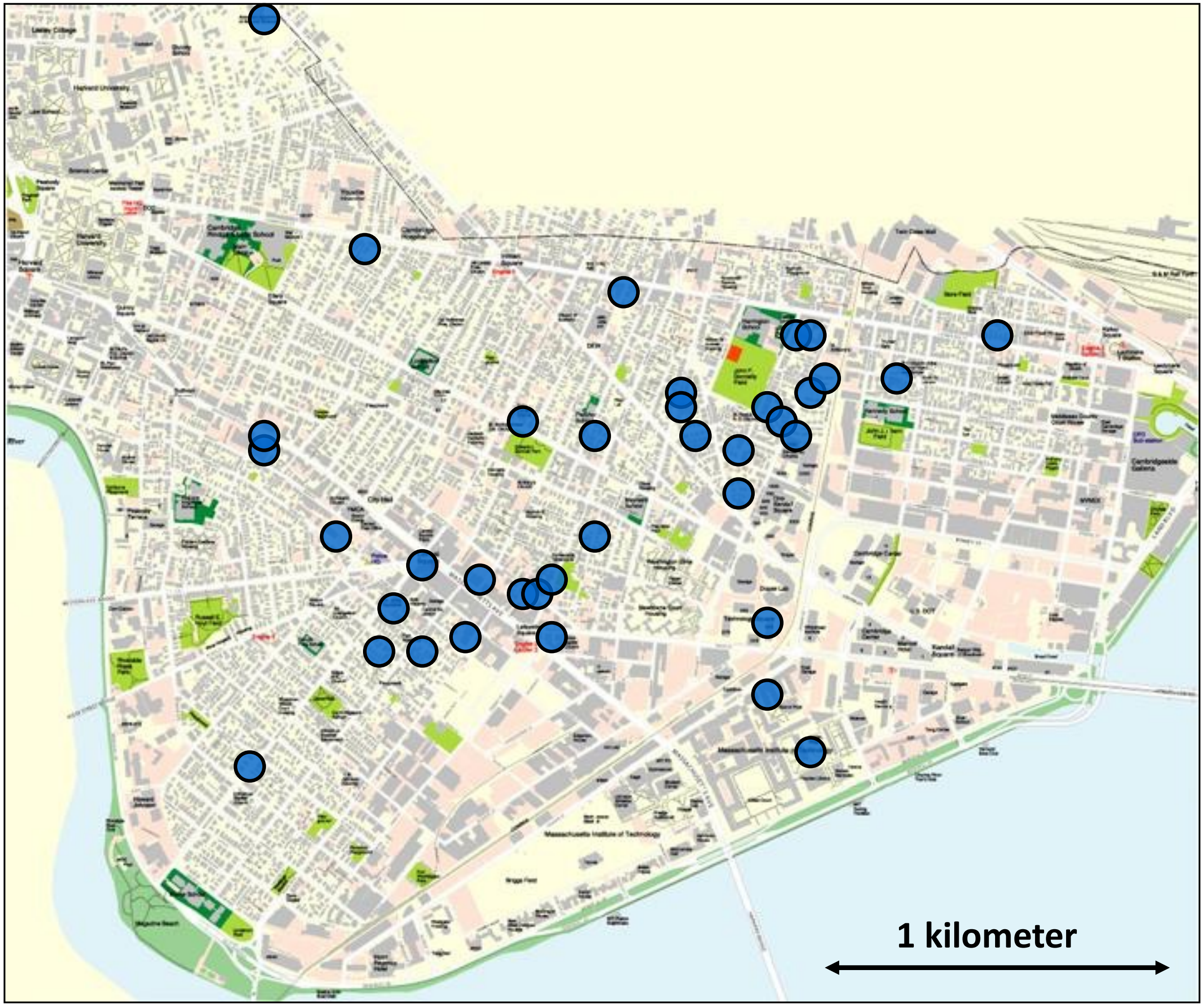
# Wireless Mesh Networks: Motivation

- Most wireless network traffic goes through APs
- Mesh networks remove this restriction
  - **Multiple paths** between most pairs: Mesh topology
- Big Impact: Home Mesh, Satellite/Balloon Internet



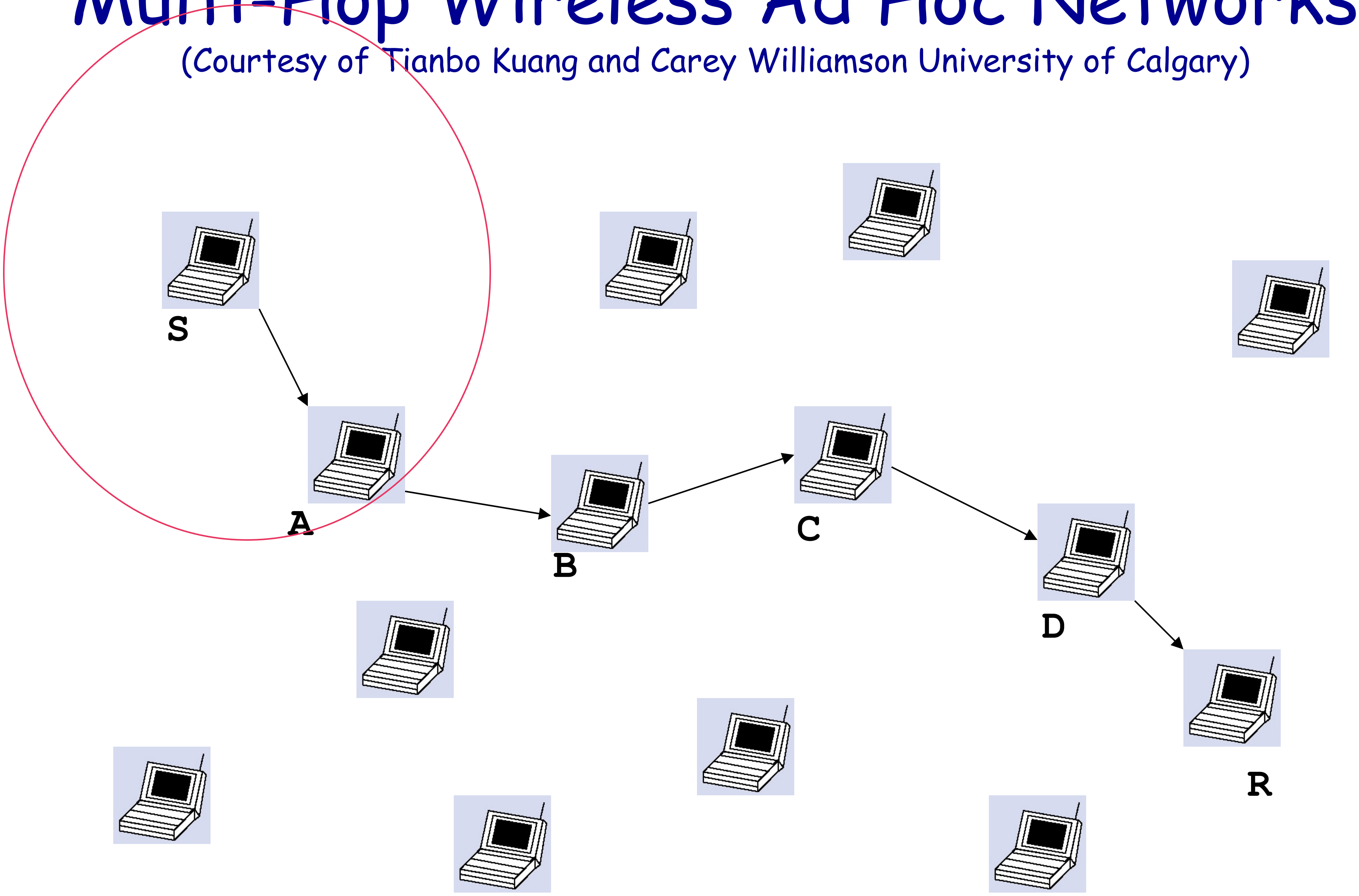
# Large Multihop Network

(courtesy of Sanjit Biswas, MIT)

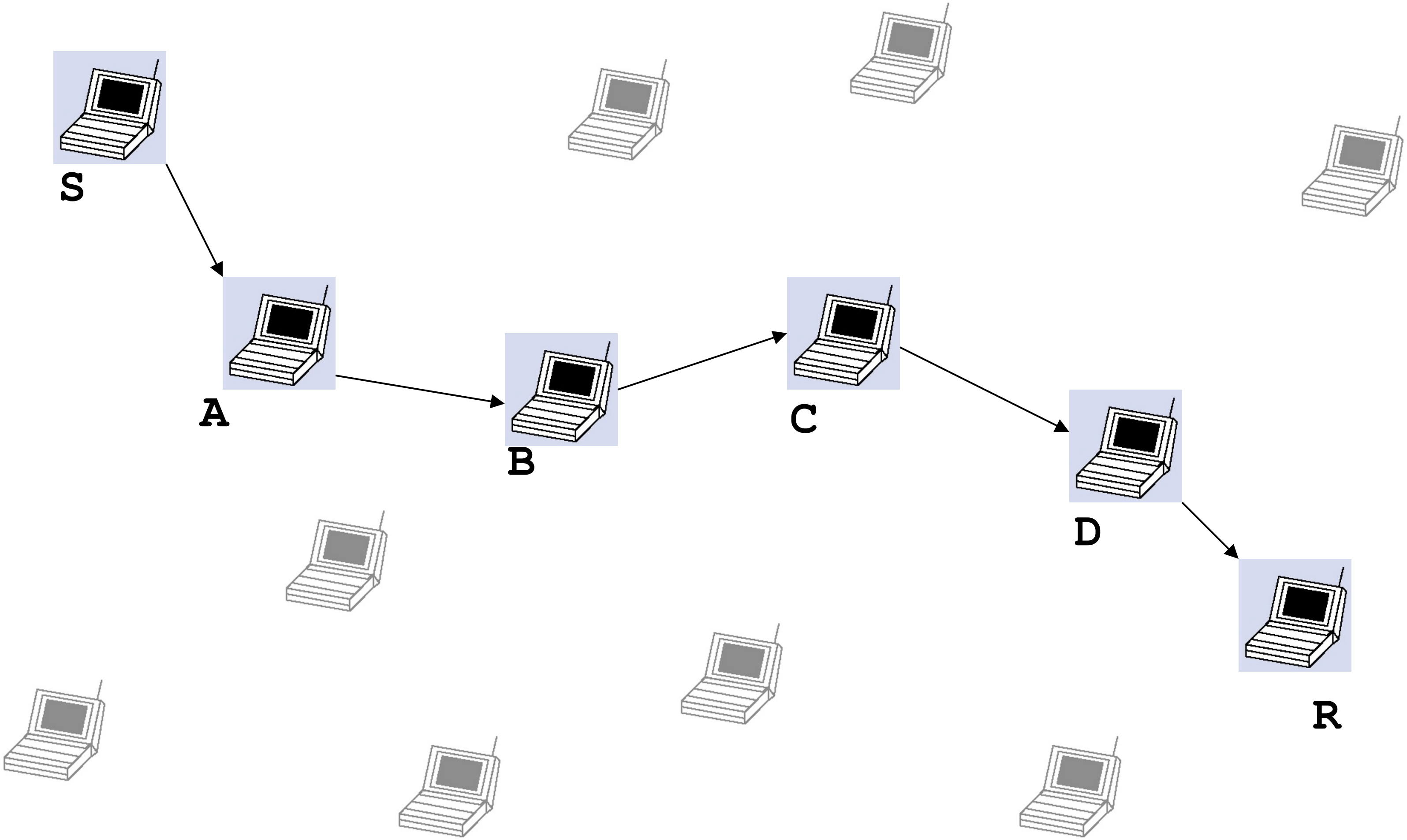


# Multi-Hop Wireless Ad Hoc Networks

(Courtesy of Tianbo Kuang and Carey Williamson University of Calgary)

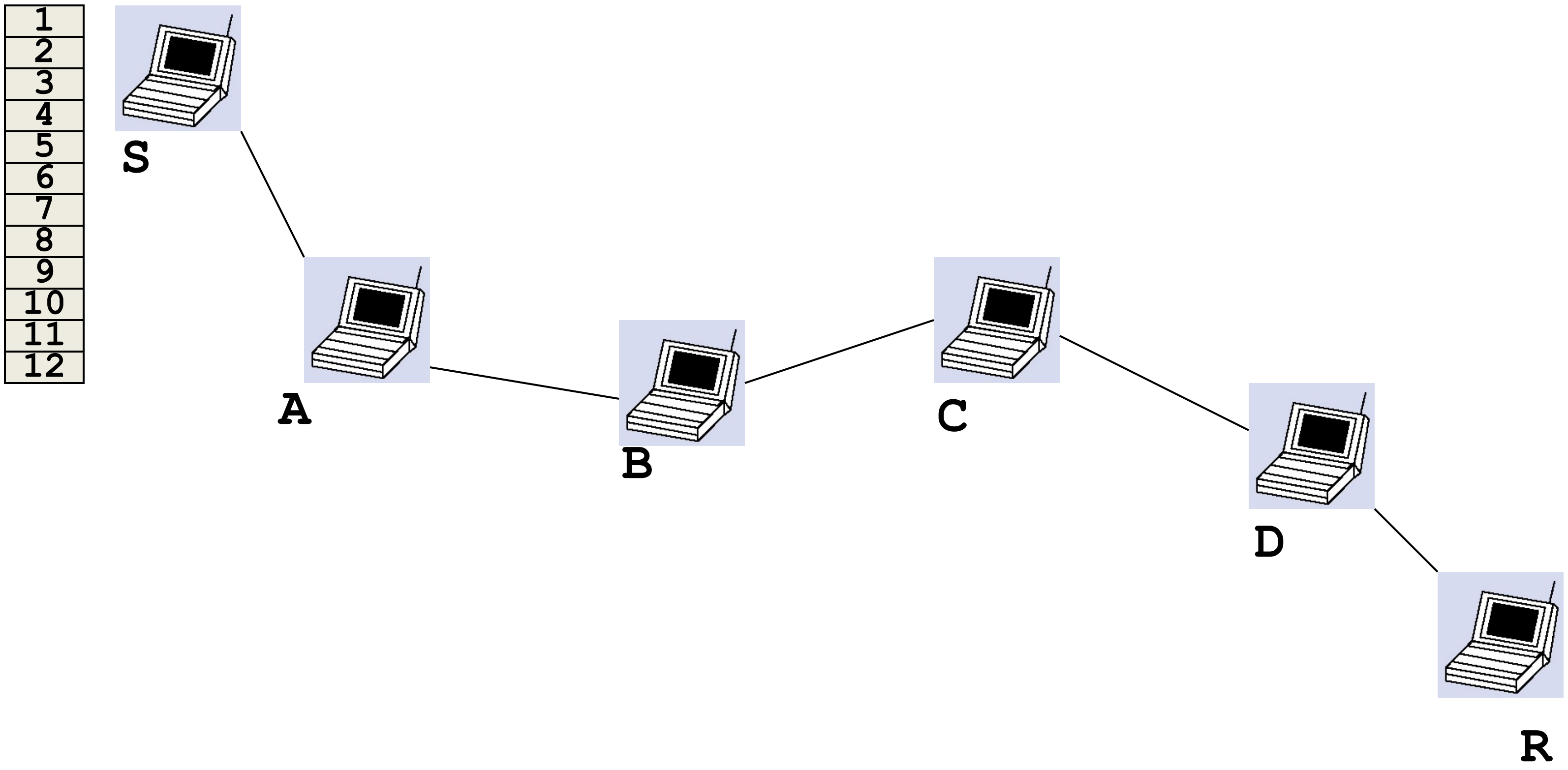


# Multi-Hop Wireless Ad Hoc Networks

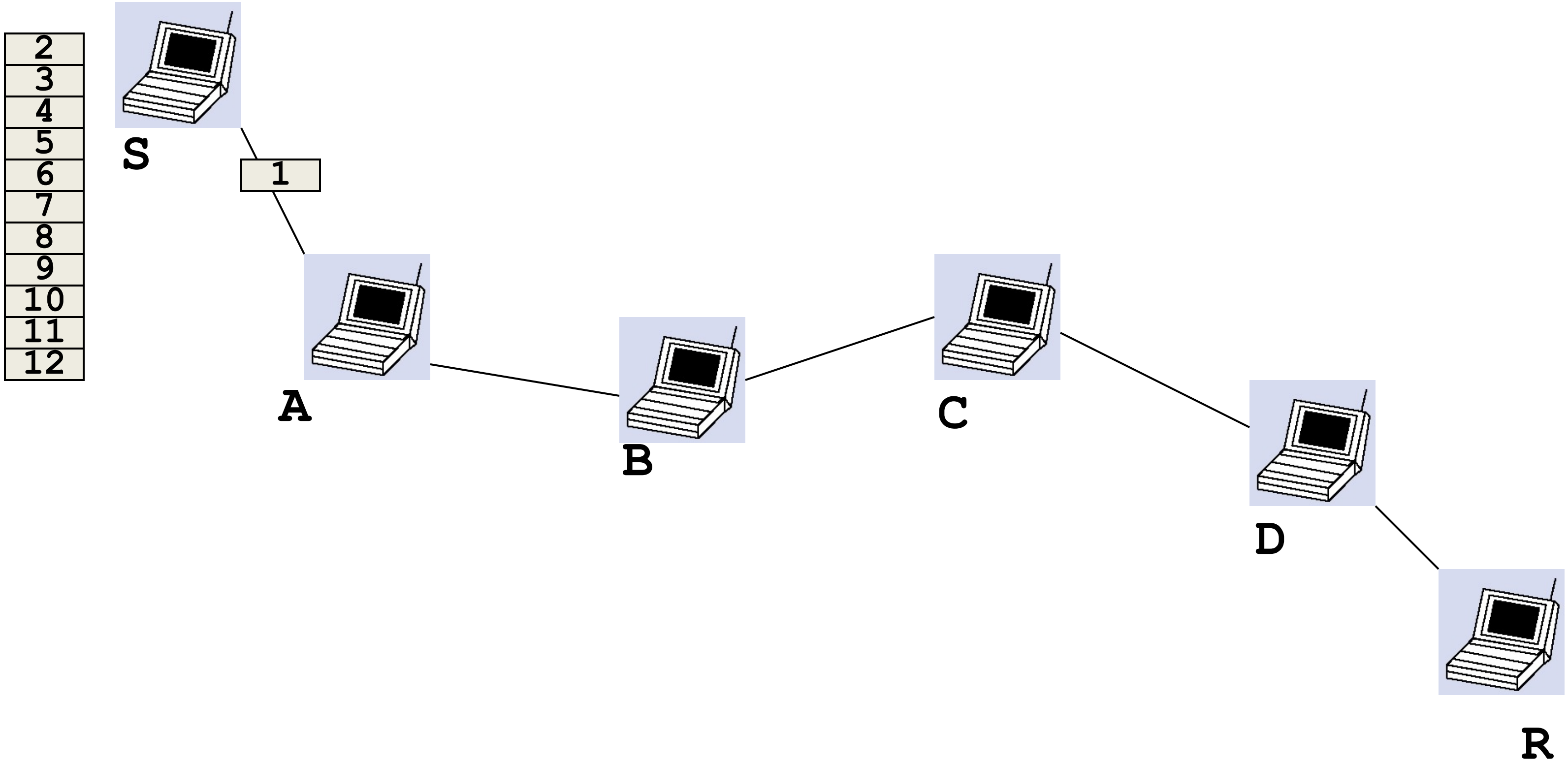


# Multi-Hop Wireless Ad Hoc Networks

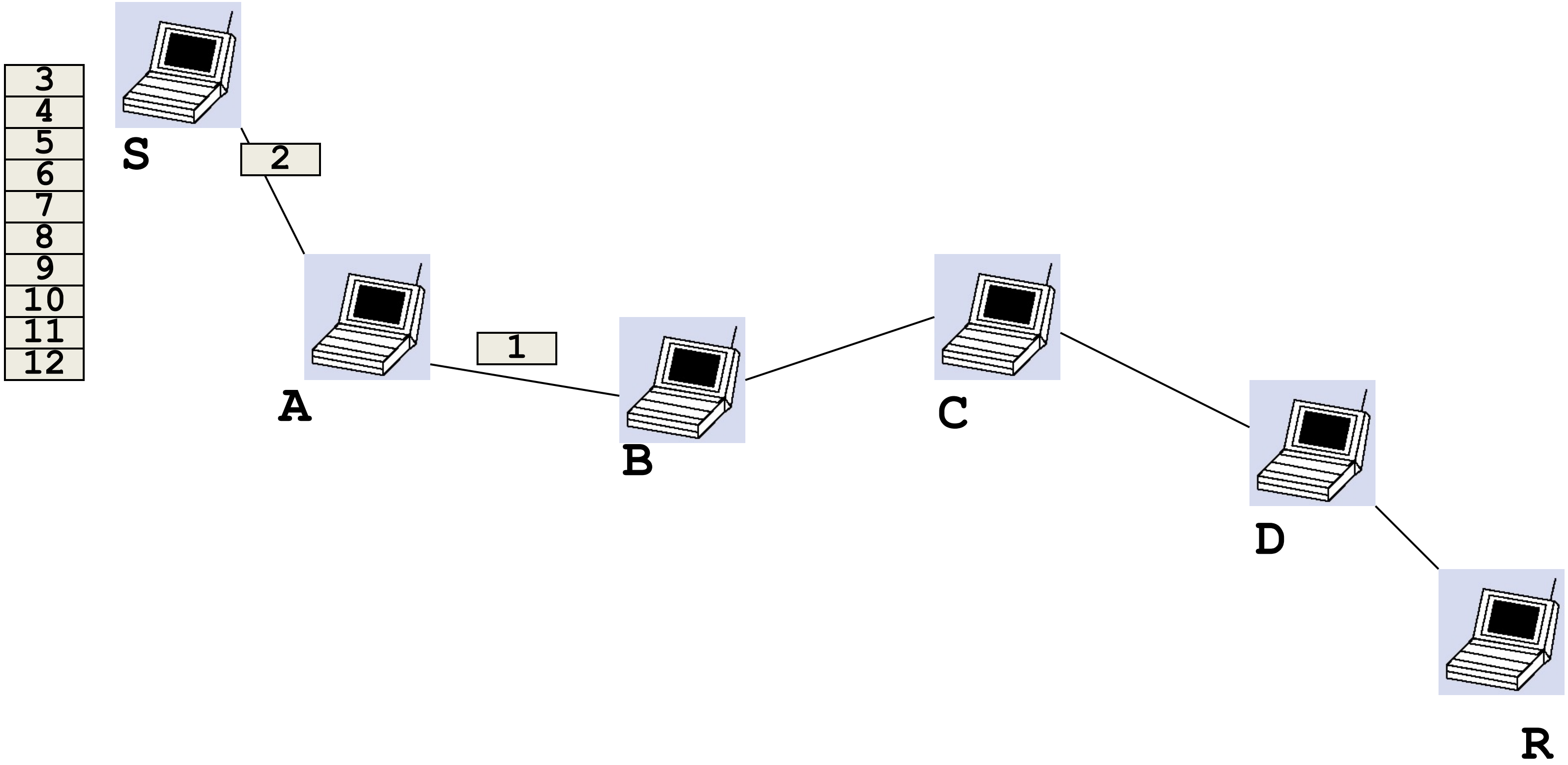
(Assume ideal world…)



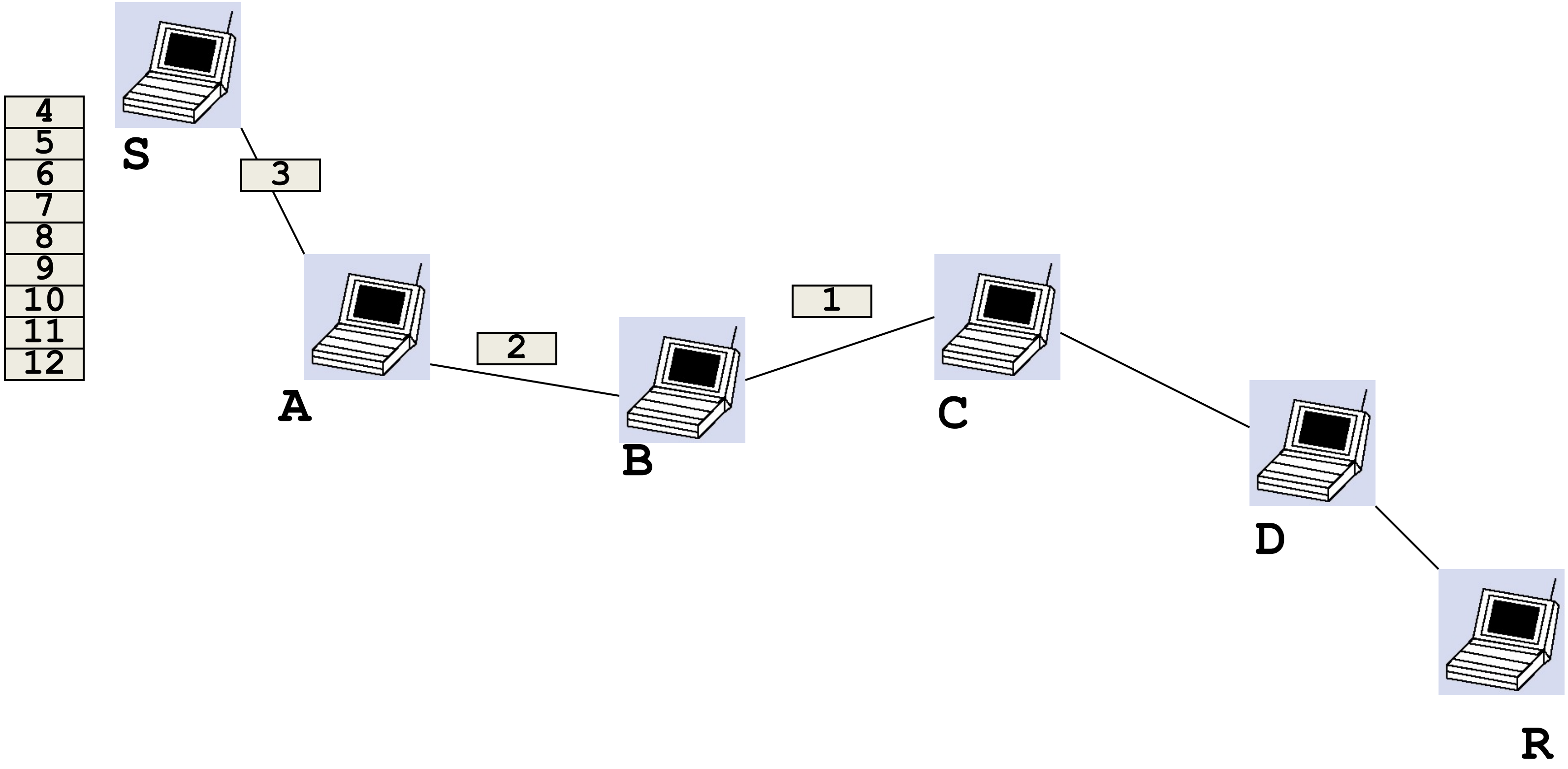
# Multi-Hop Wireless Ad Hoc Networks



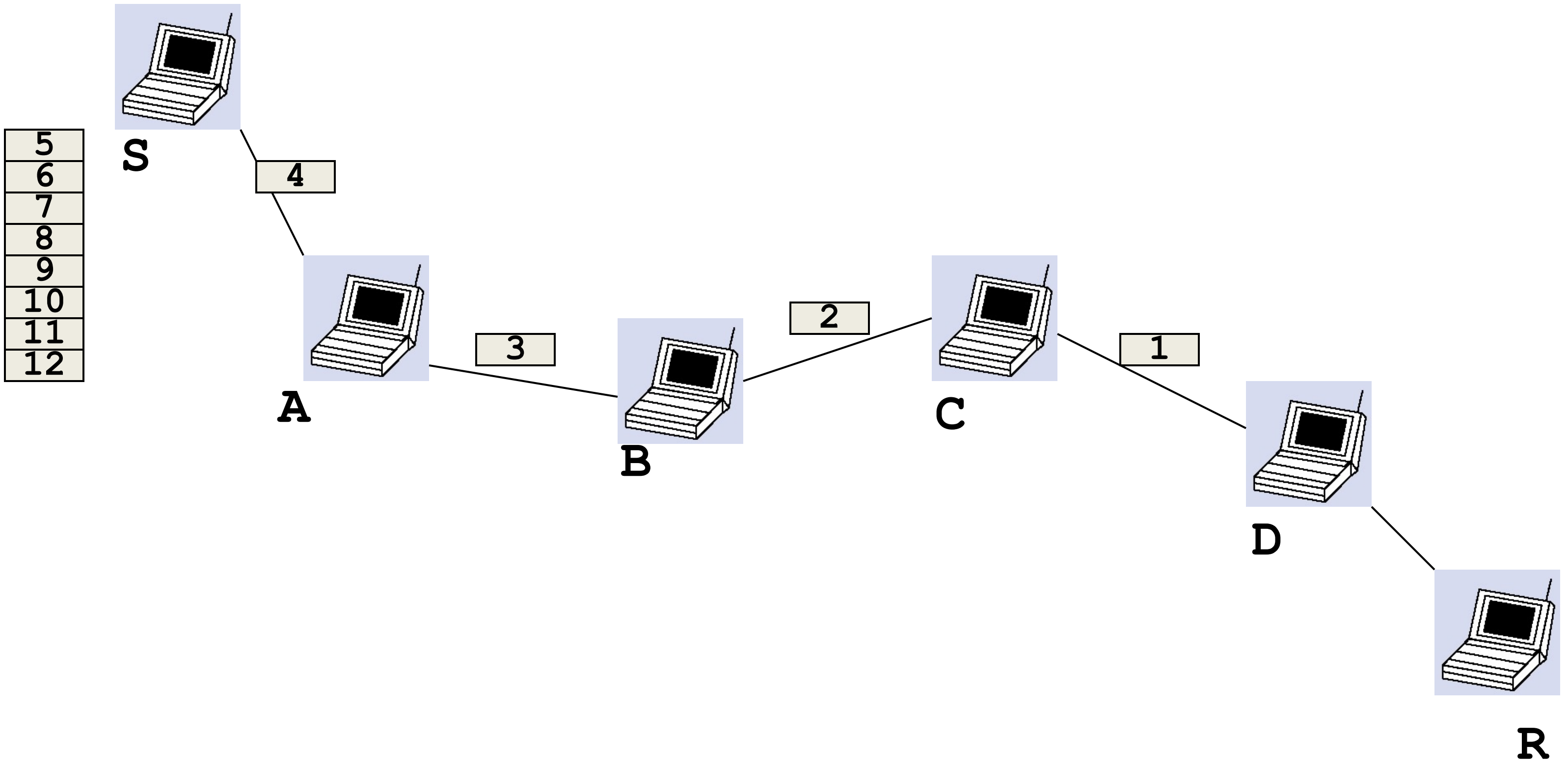
# Multi-Hop Wireless Ad Hoc Networks



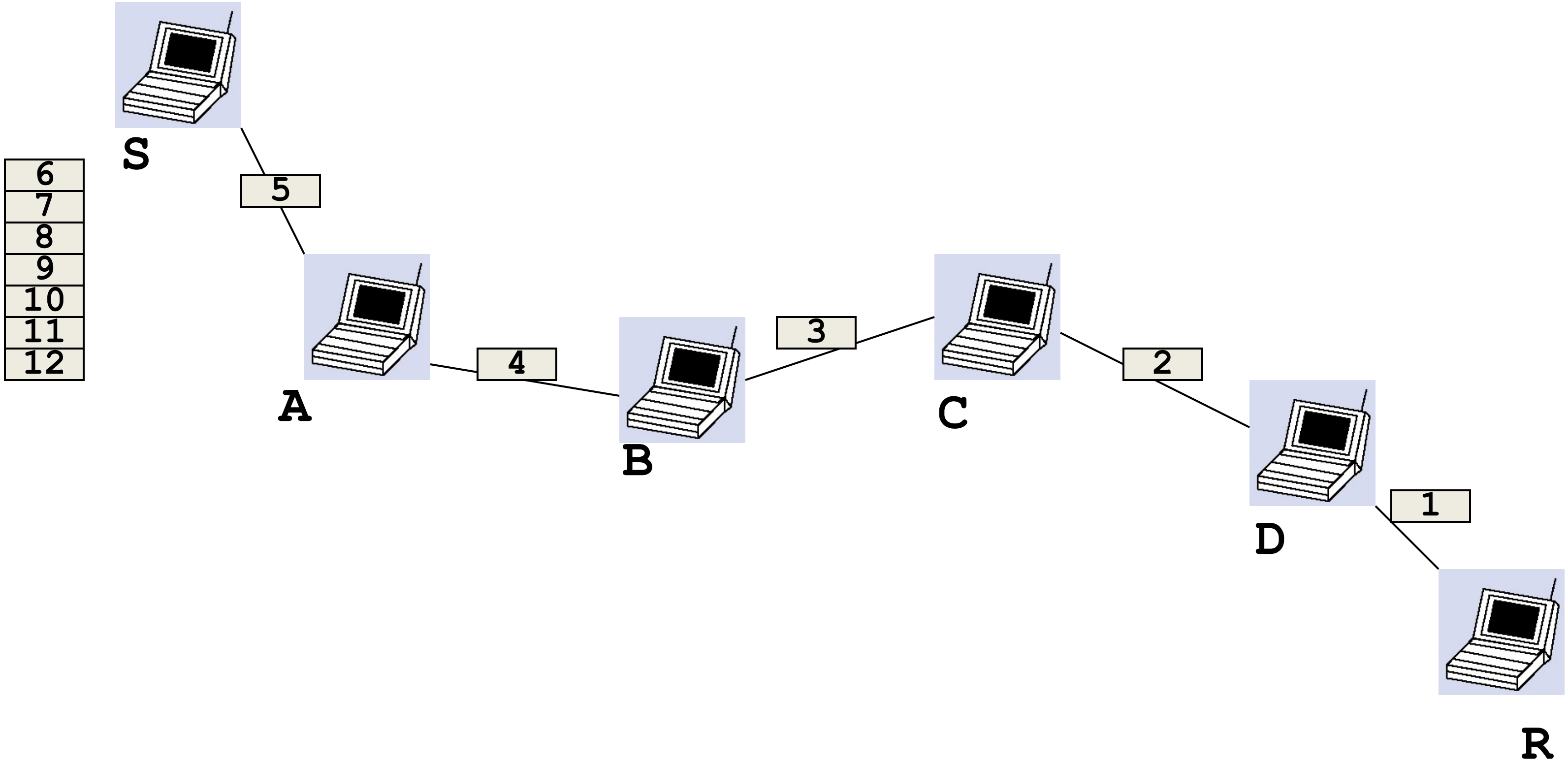
# Multi-Hop Wireless Ad Hoc Networks



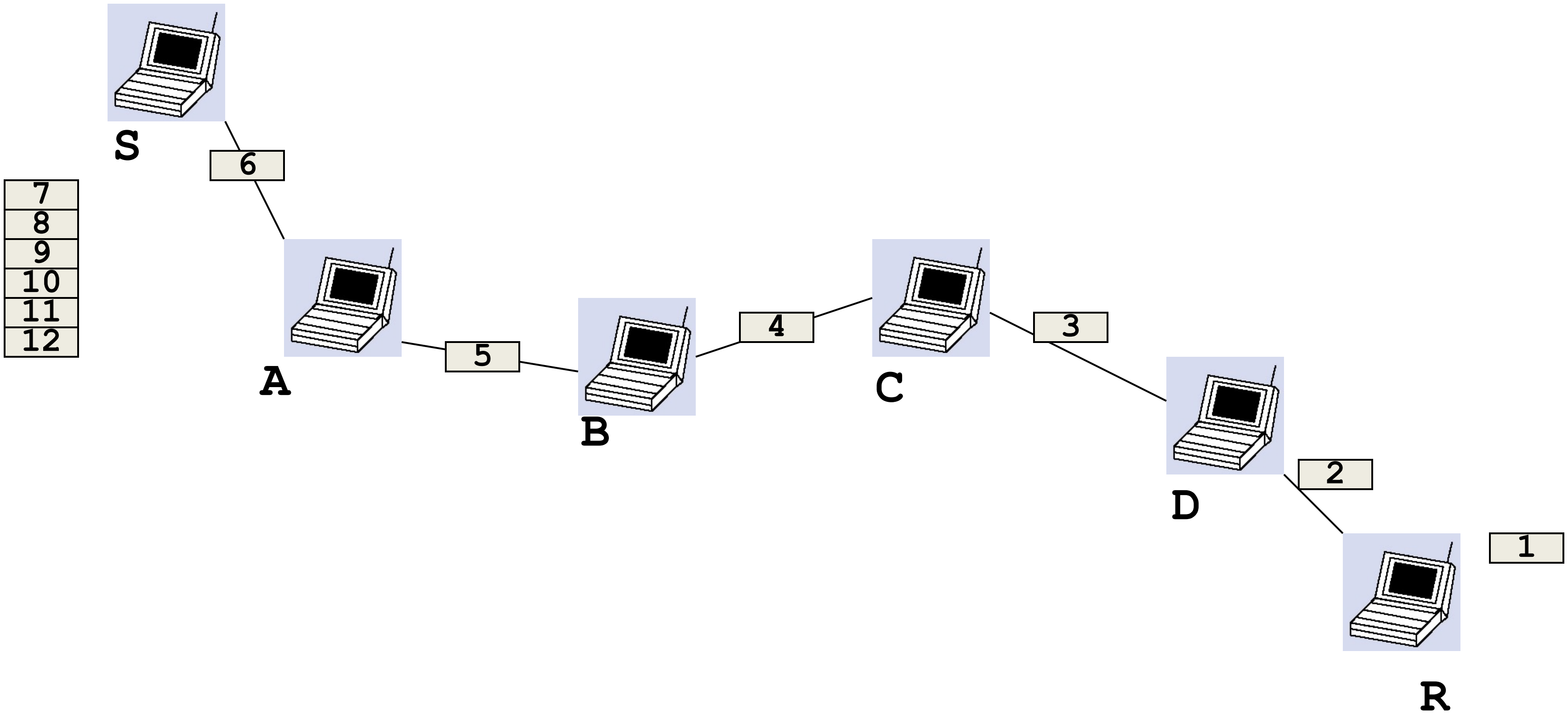
# Multi-Hop Wireless Ad Hoc Networks



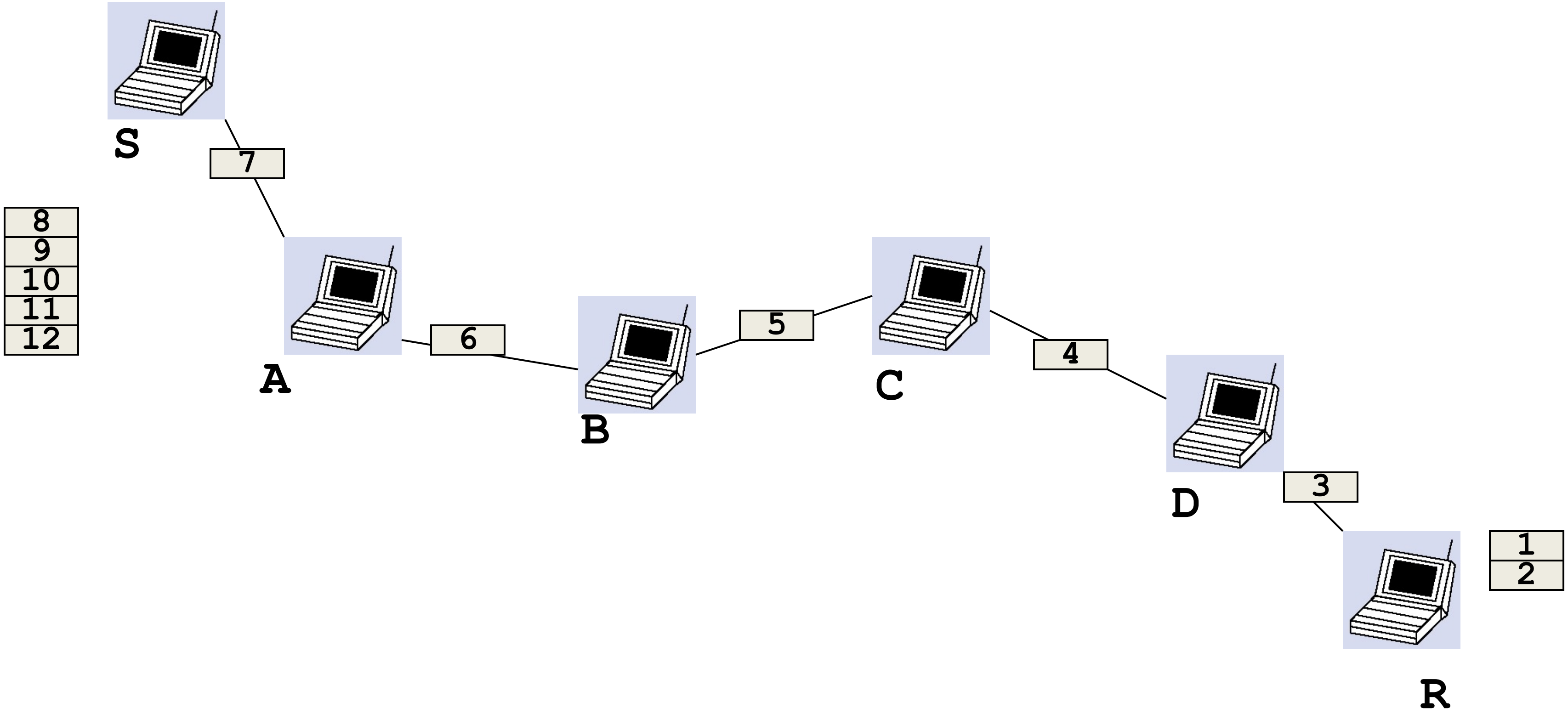
# Multi-Hop Wireless Ad Hoc Networks



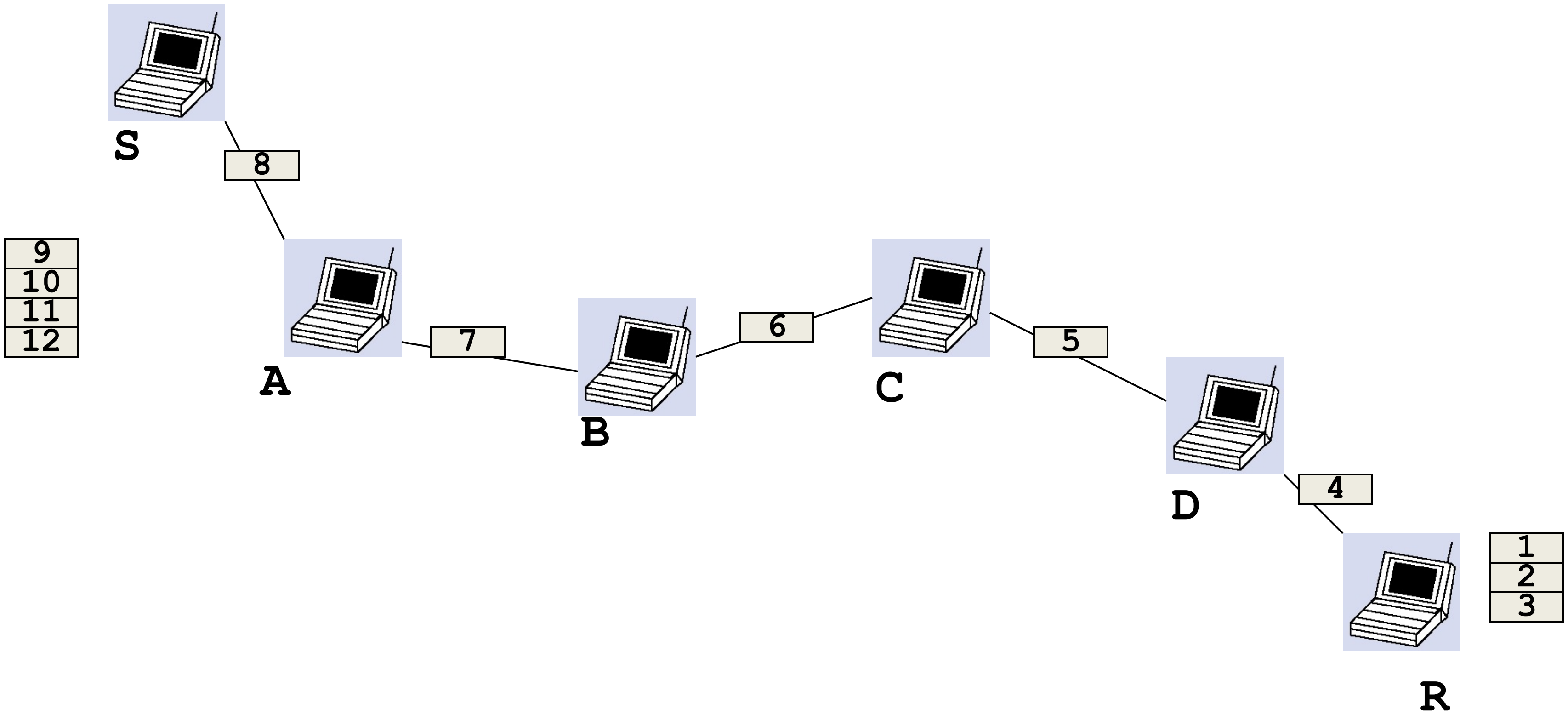
# Multi-Hop Wireless Ad Hoc Networks



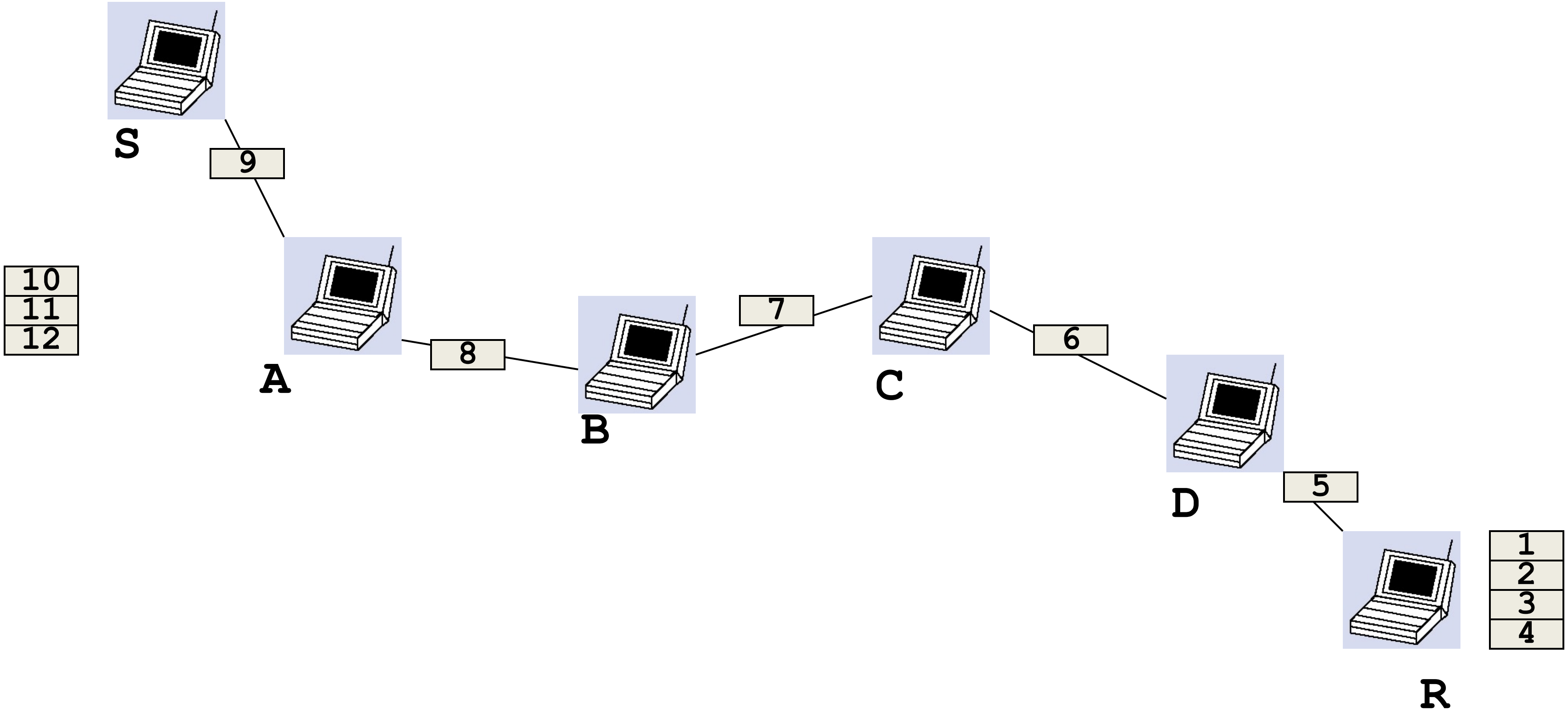
# Multi-Hop Wireless Ad Hoc Networks



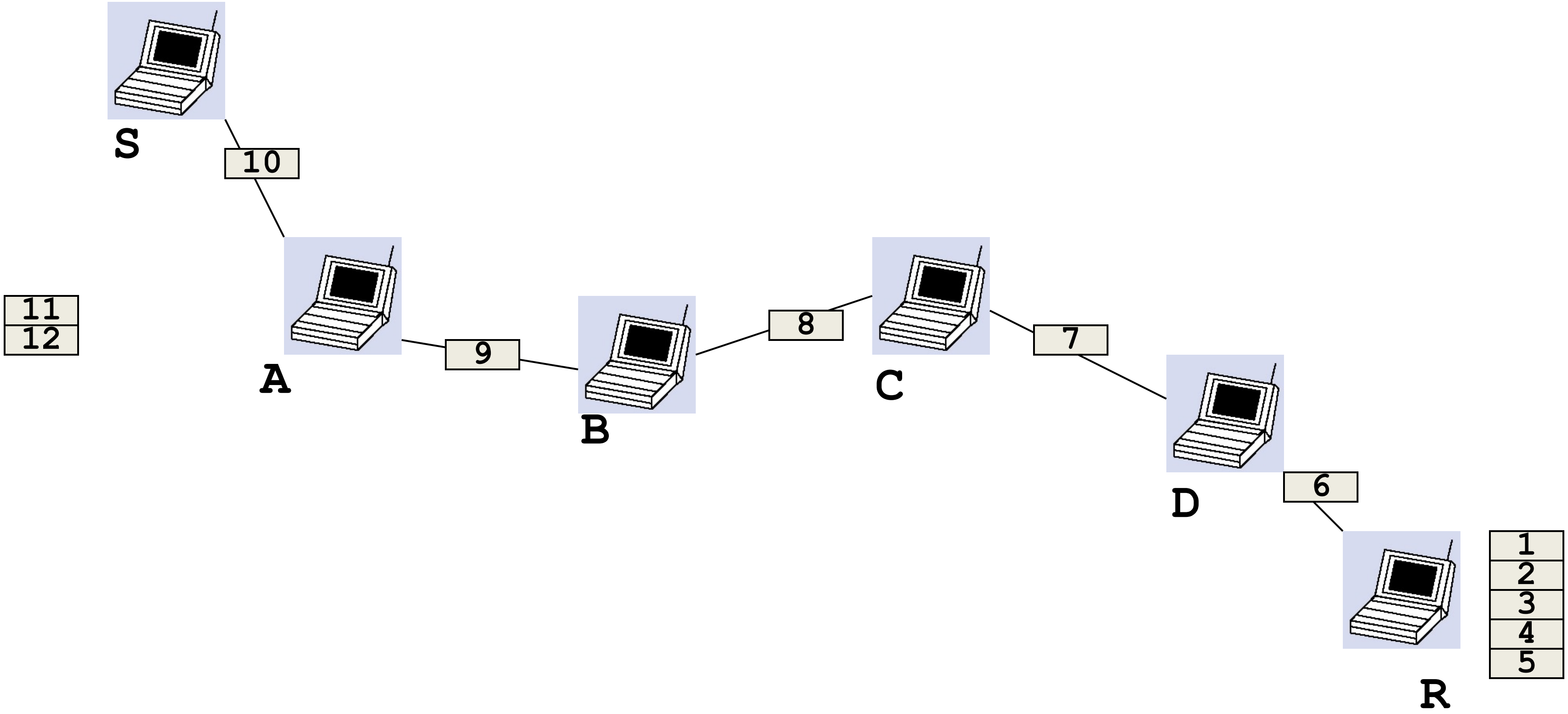
# Multi-Hop Wireless Ad Hoc Networks



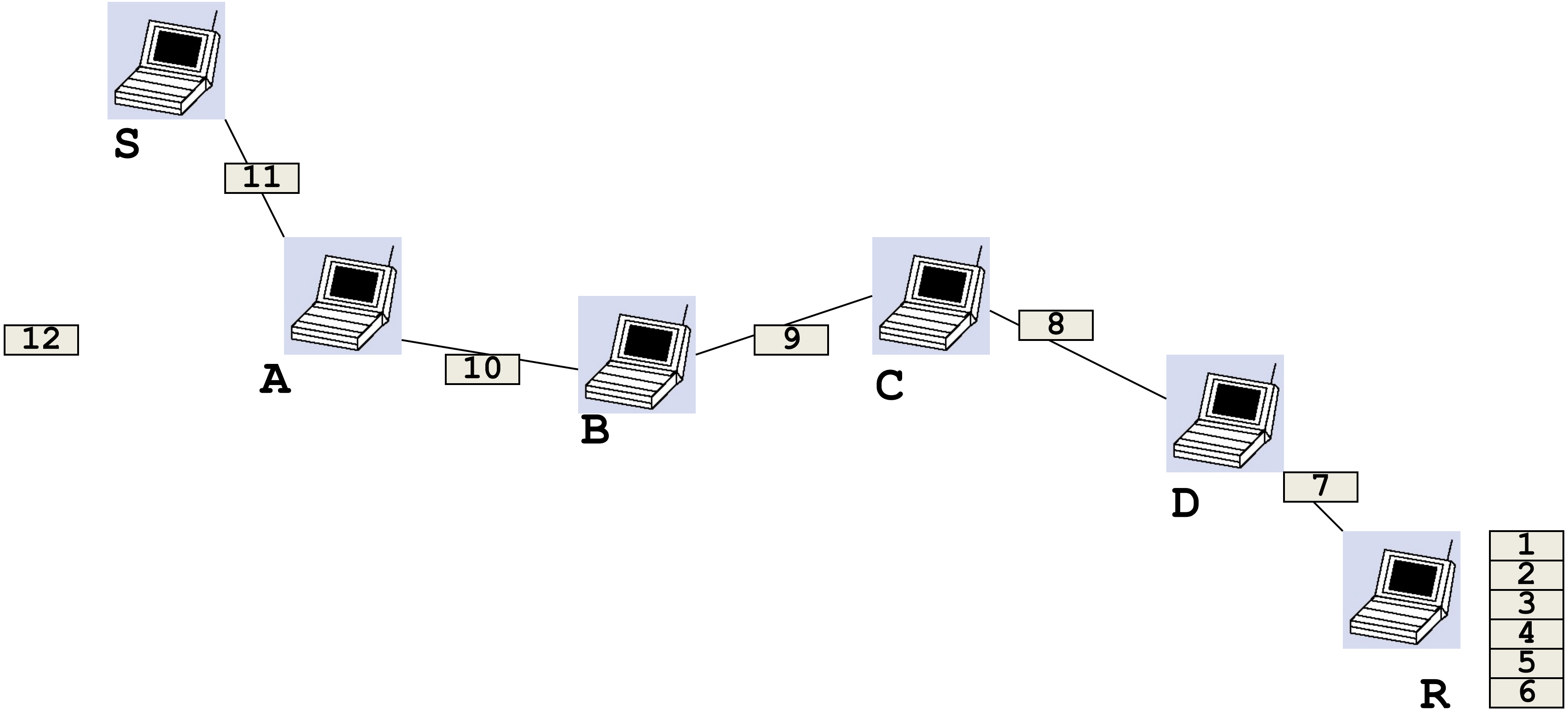
# Multi-Hop Wireless Ad Hoc Networks



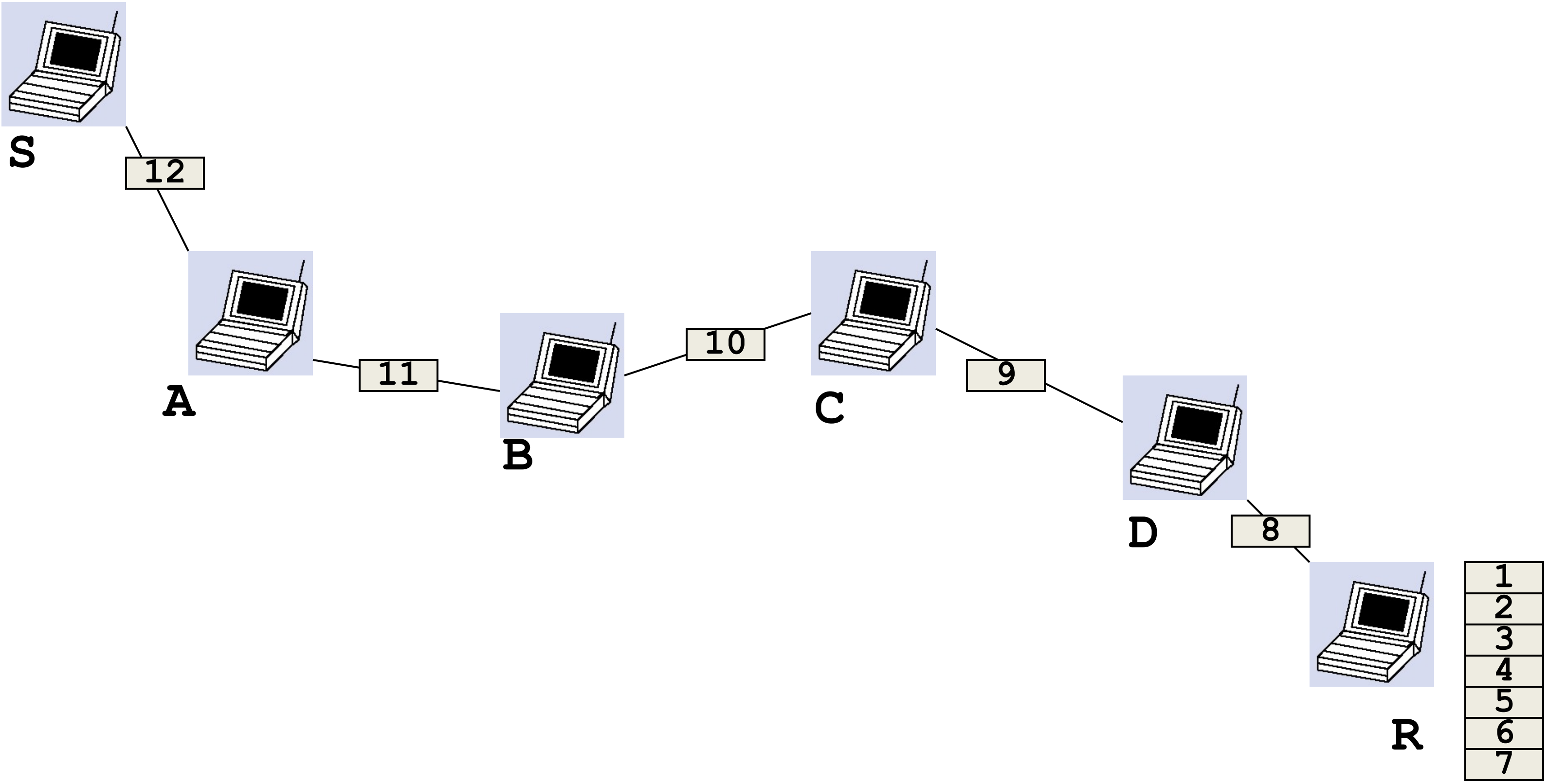
# Multi-Hop Wireless Ad Hoc Networks



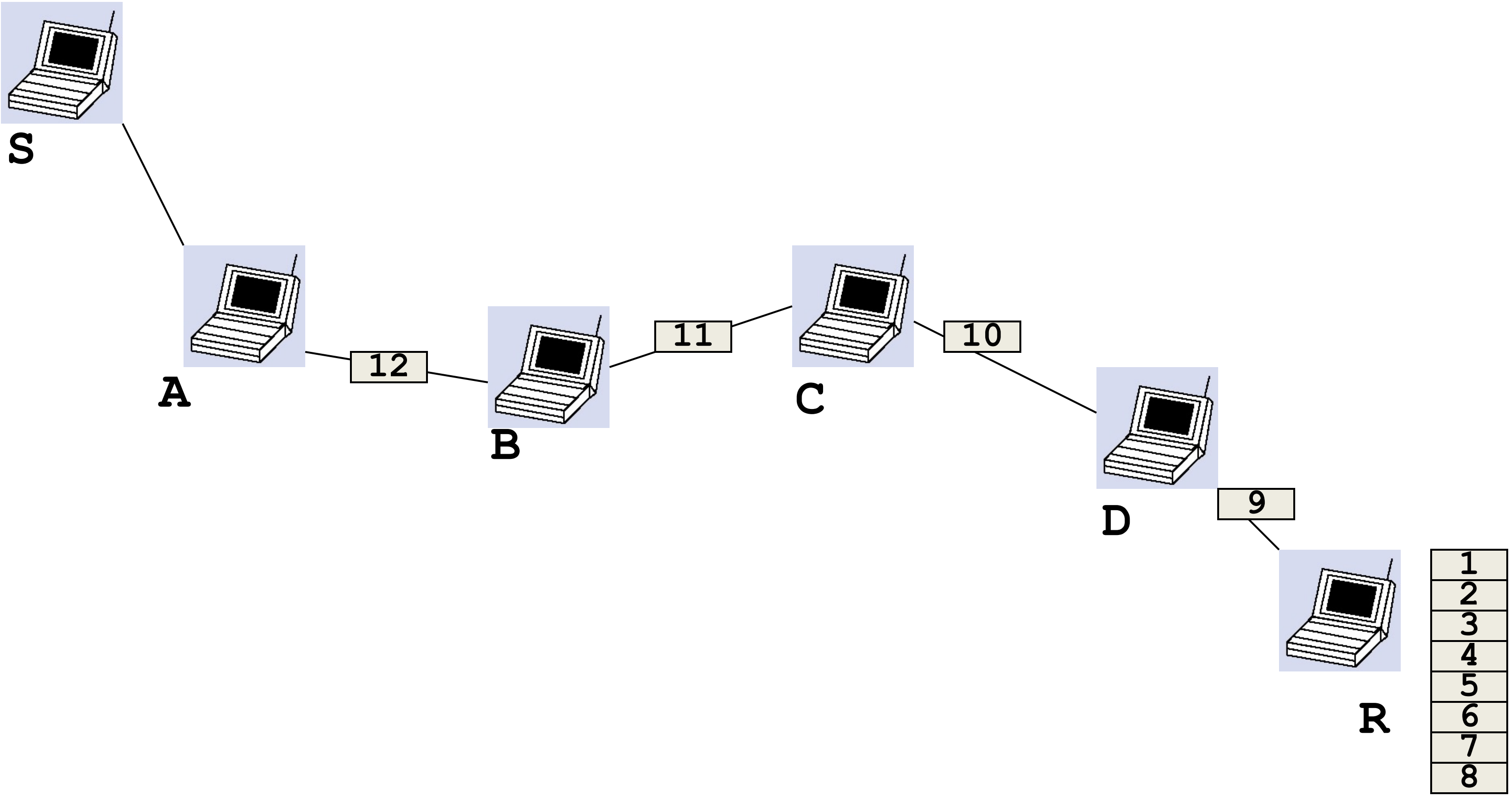
# Multi-Hop Wireless Ad Hoc Networks



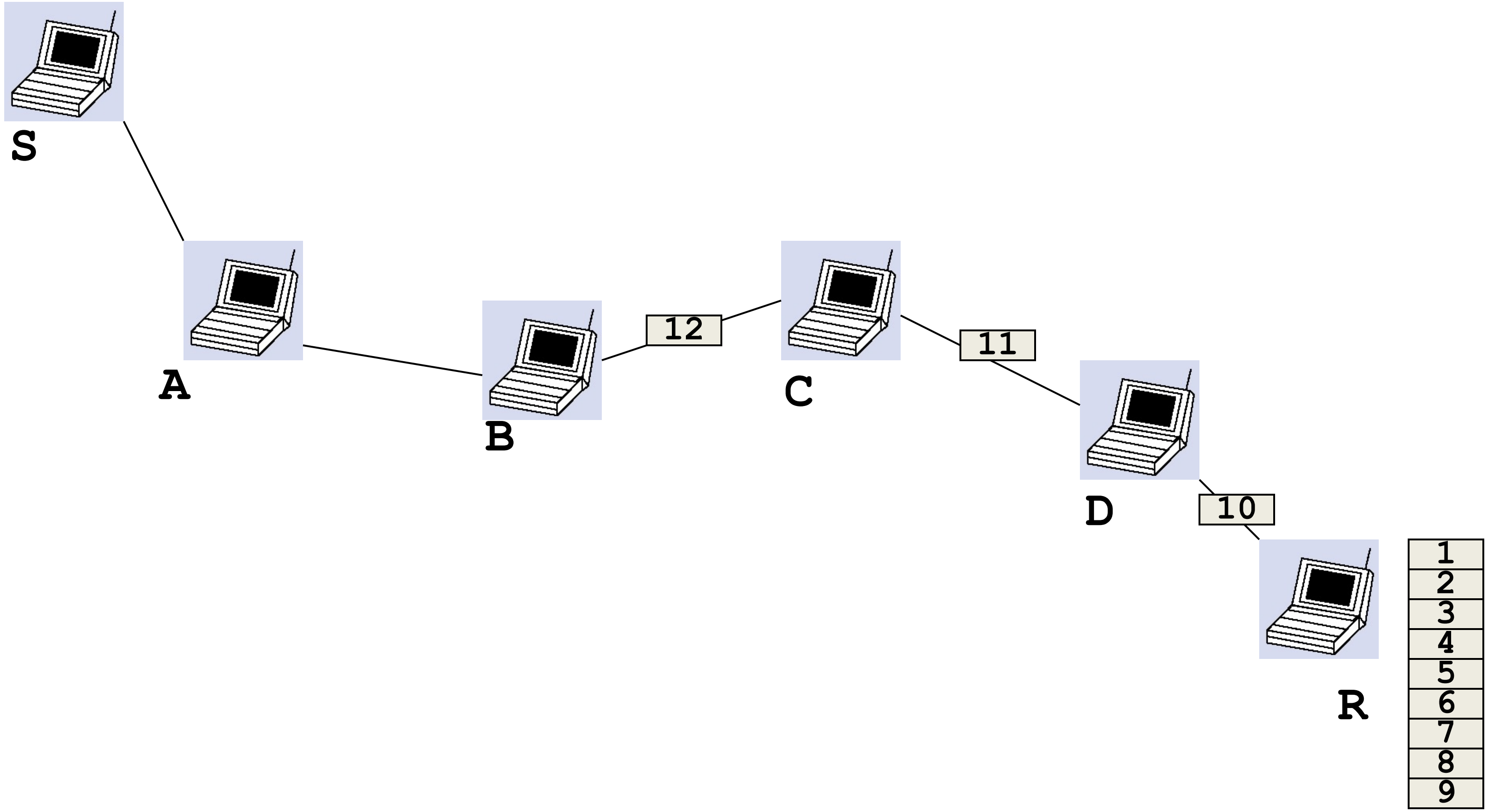
# Multi-Hop Wireless Ad Hoc Networks



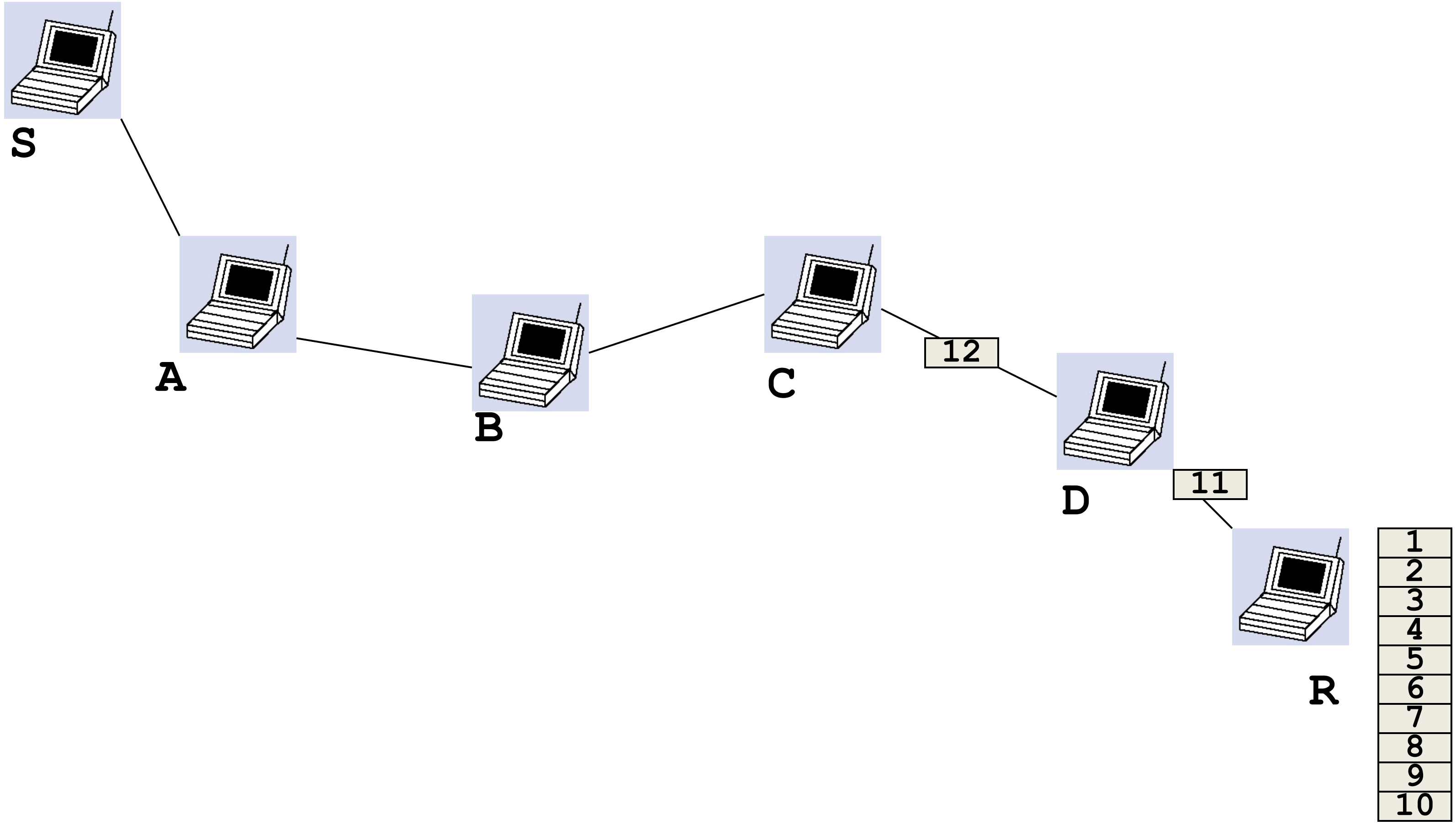
# Multi-Hop Wireless Ad Hoc Networks



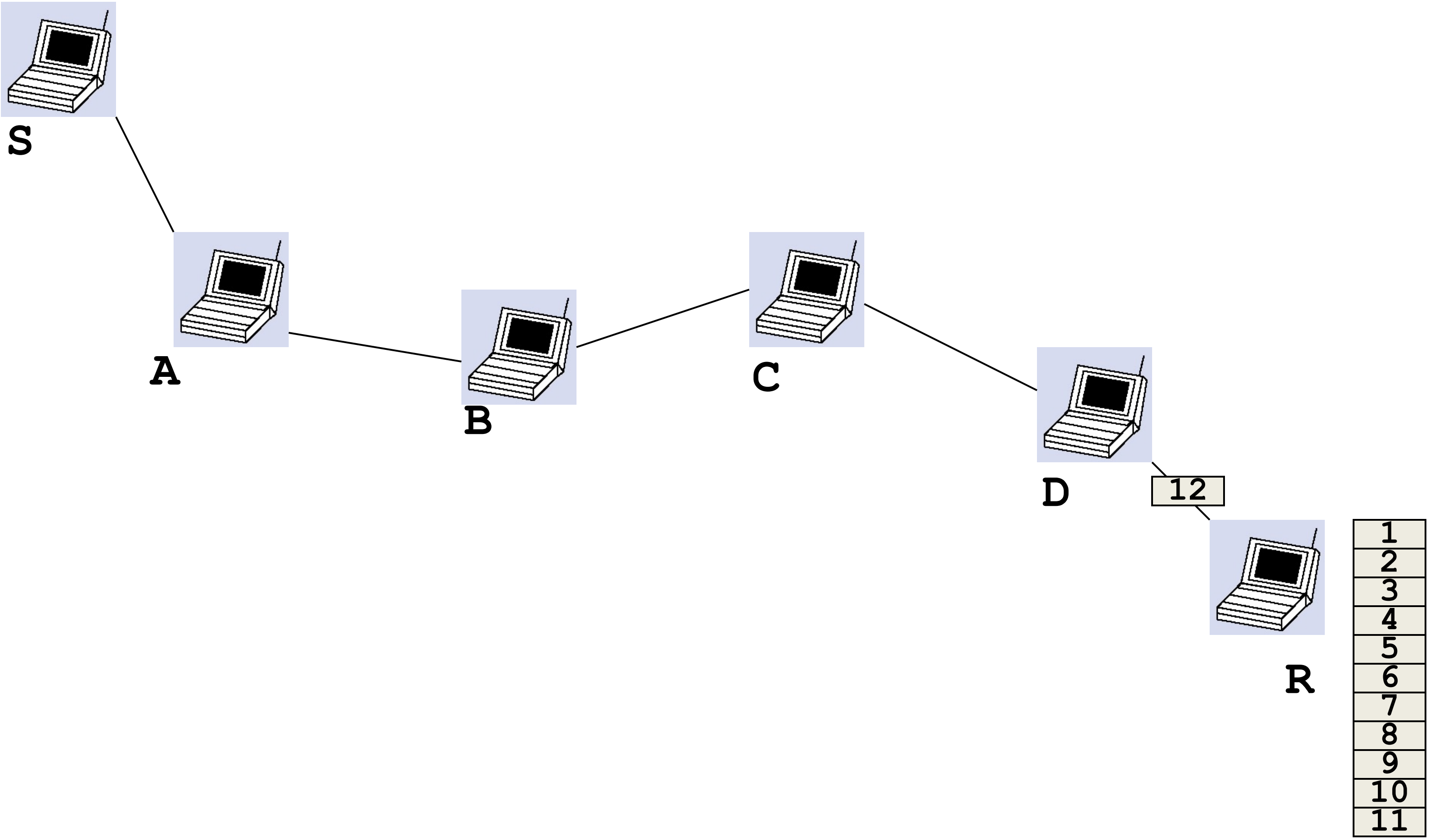
# Multi-Hop Wireless Ad Hoc Networks



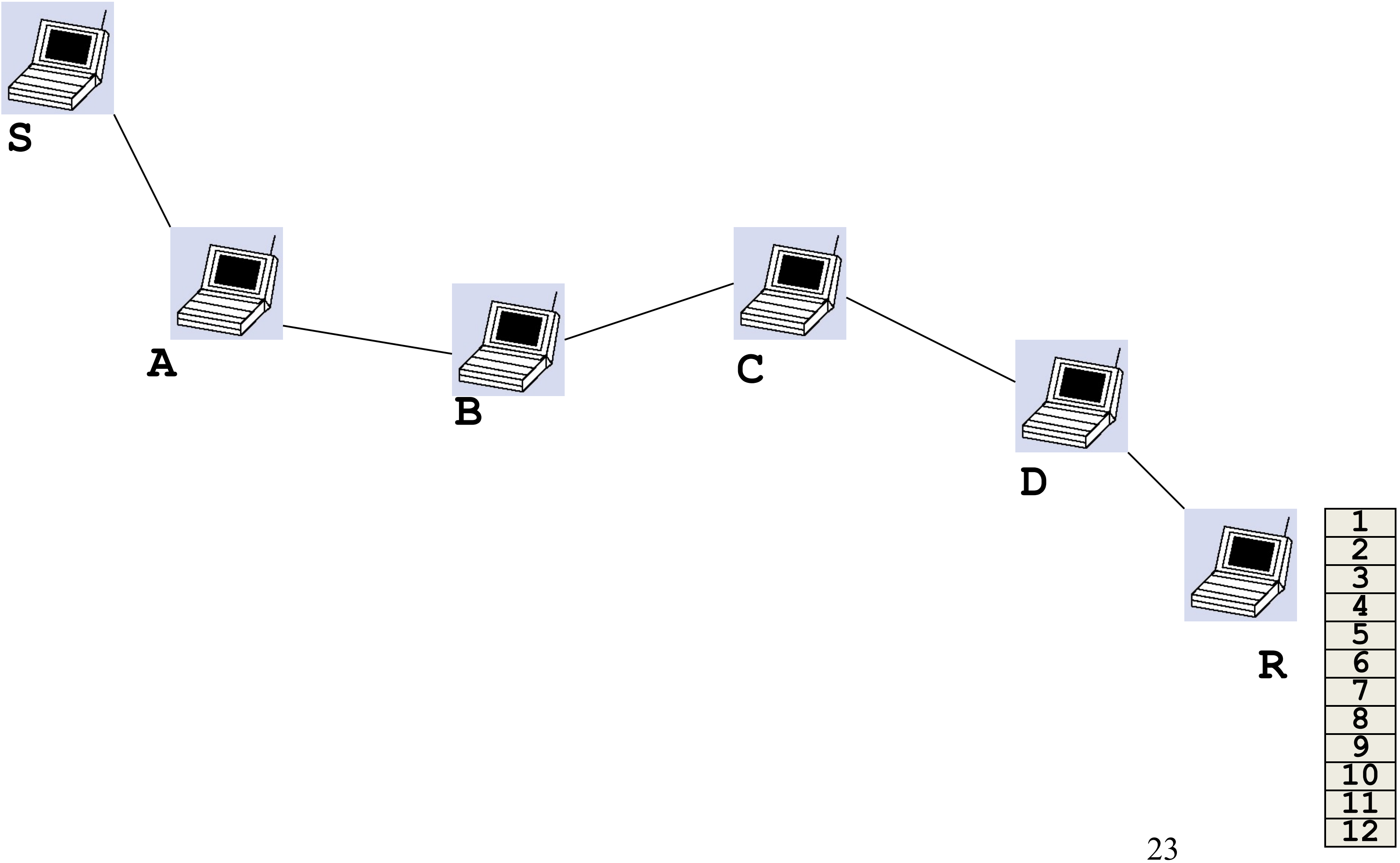
# Multi-Hop Wireless Ad Hoc Networks



# Multi-Hop Wireless Ad Hoc Networks



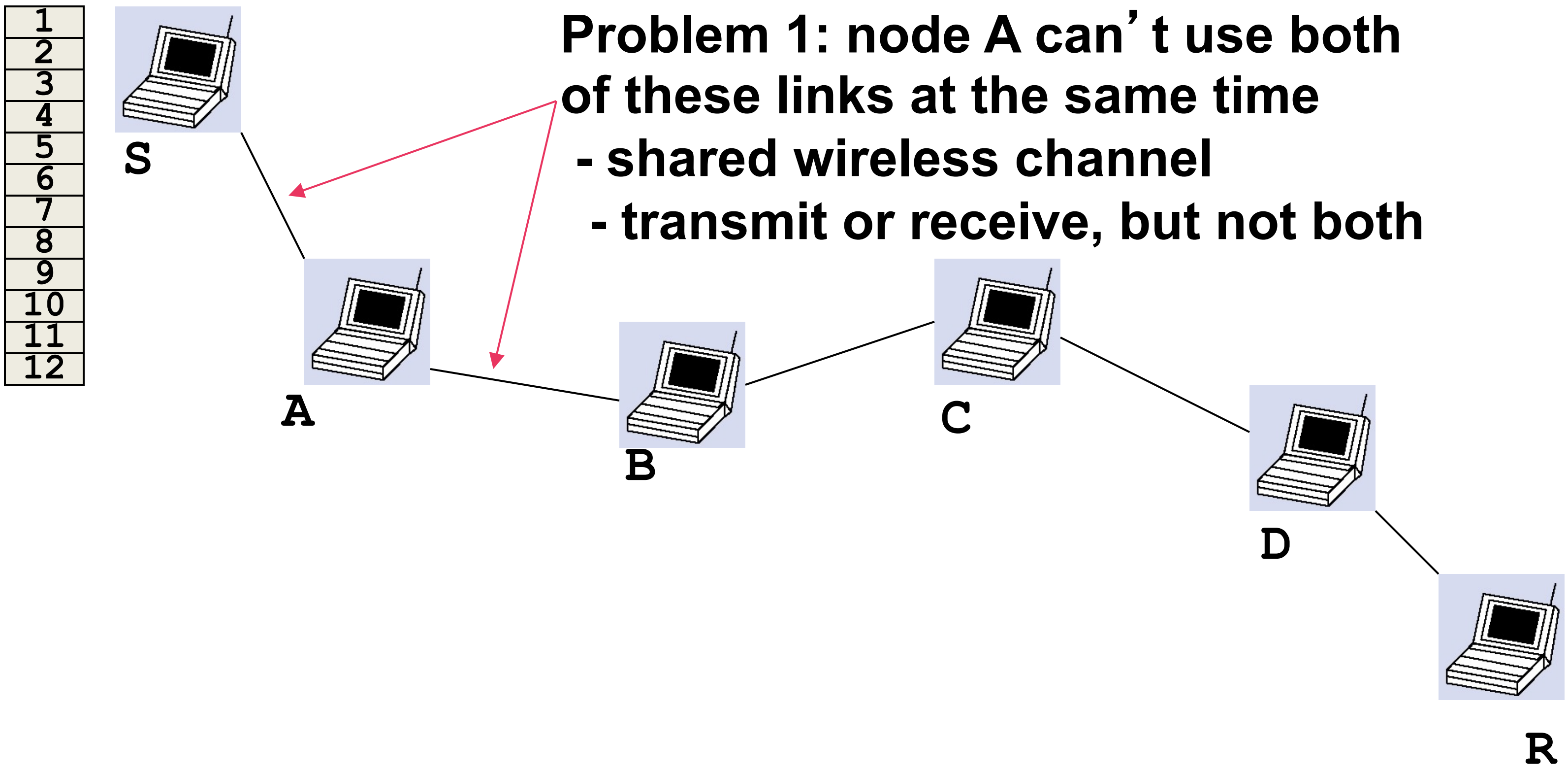
# Multi-Hop Wireless Ad Hoc Networks



# What Do YOU Think Really Happens?

# Multi-Hop Wireless Ad Hoc Networks

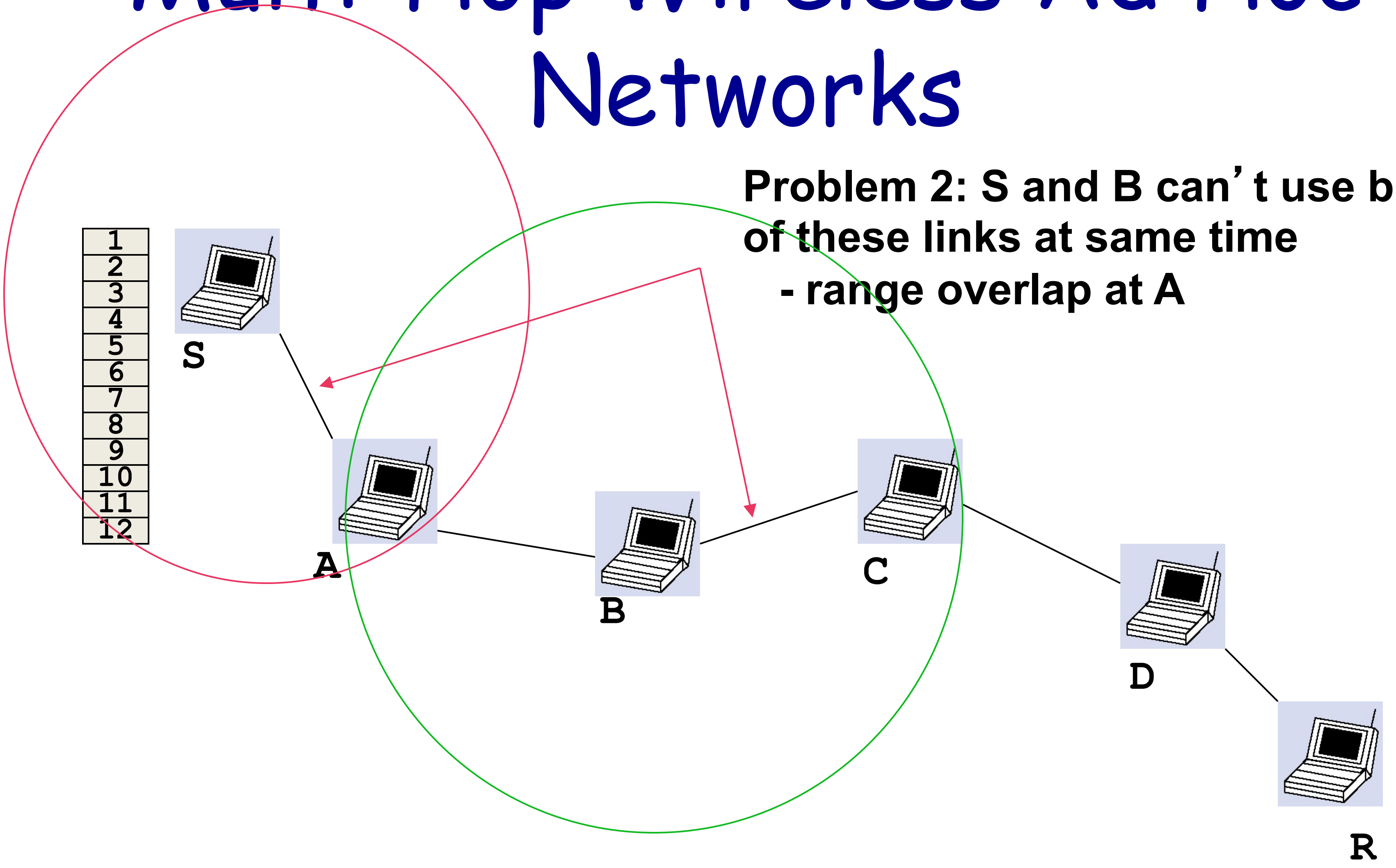
(Reality check…)



Problem 1: node A can’t use both of these links at the same time

- shared wireless channel
- transmit or receive, but not both

# Multi-Hop Wireless Ad Hoc Networks

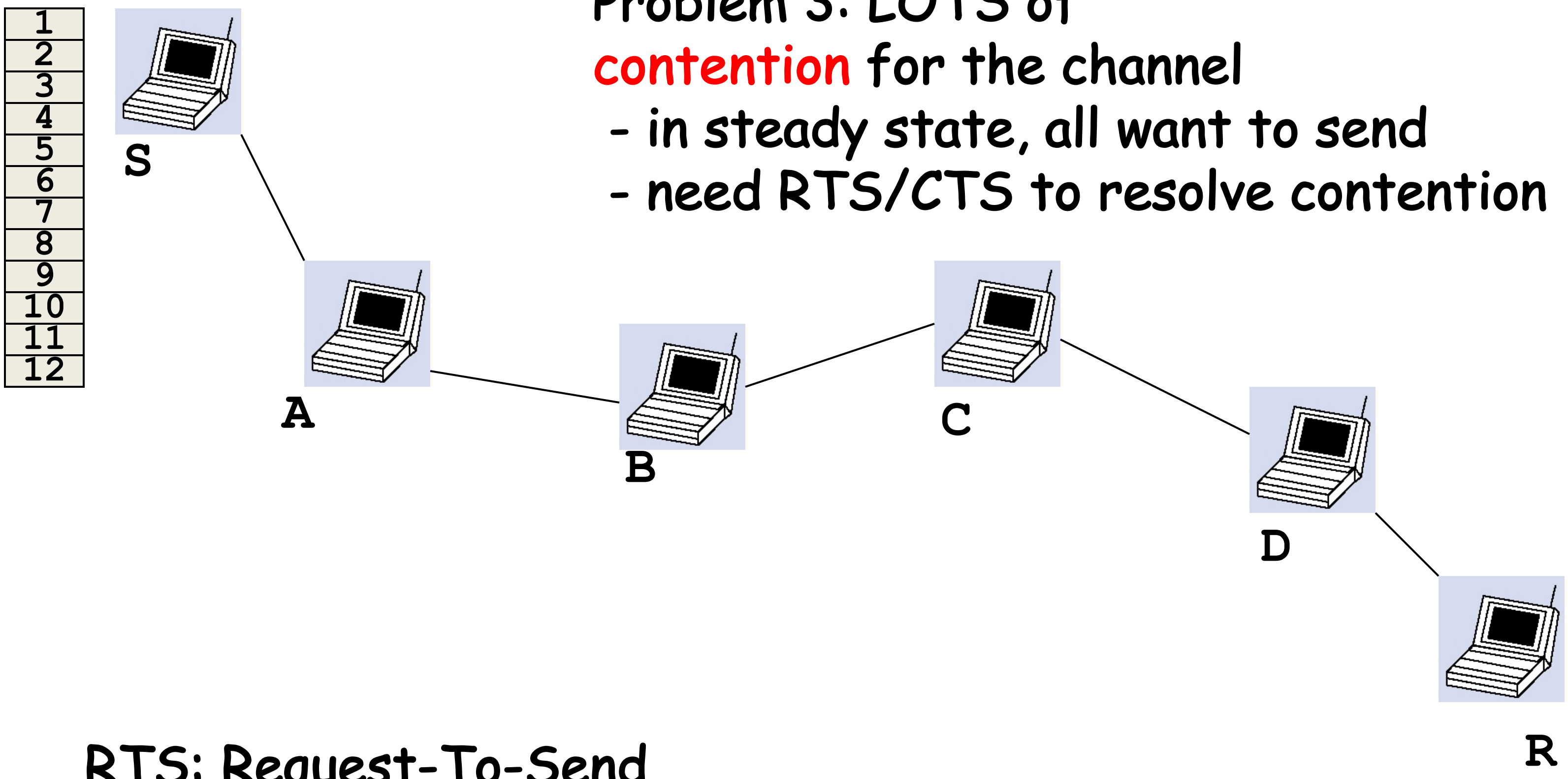


Problem 2: S and B can’t use both of these links at same time

- range overlap at A

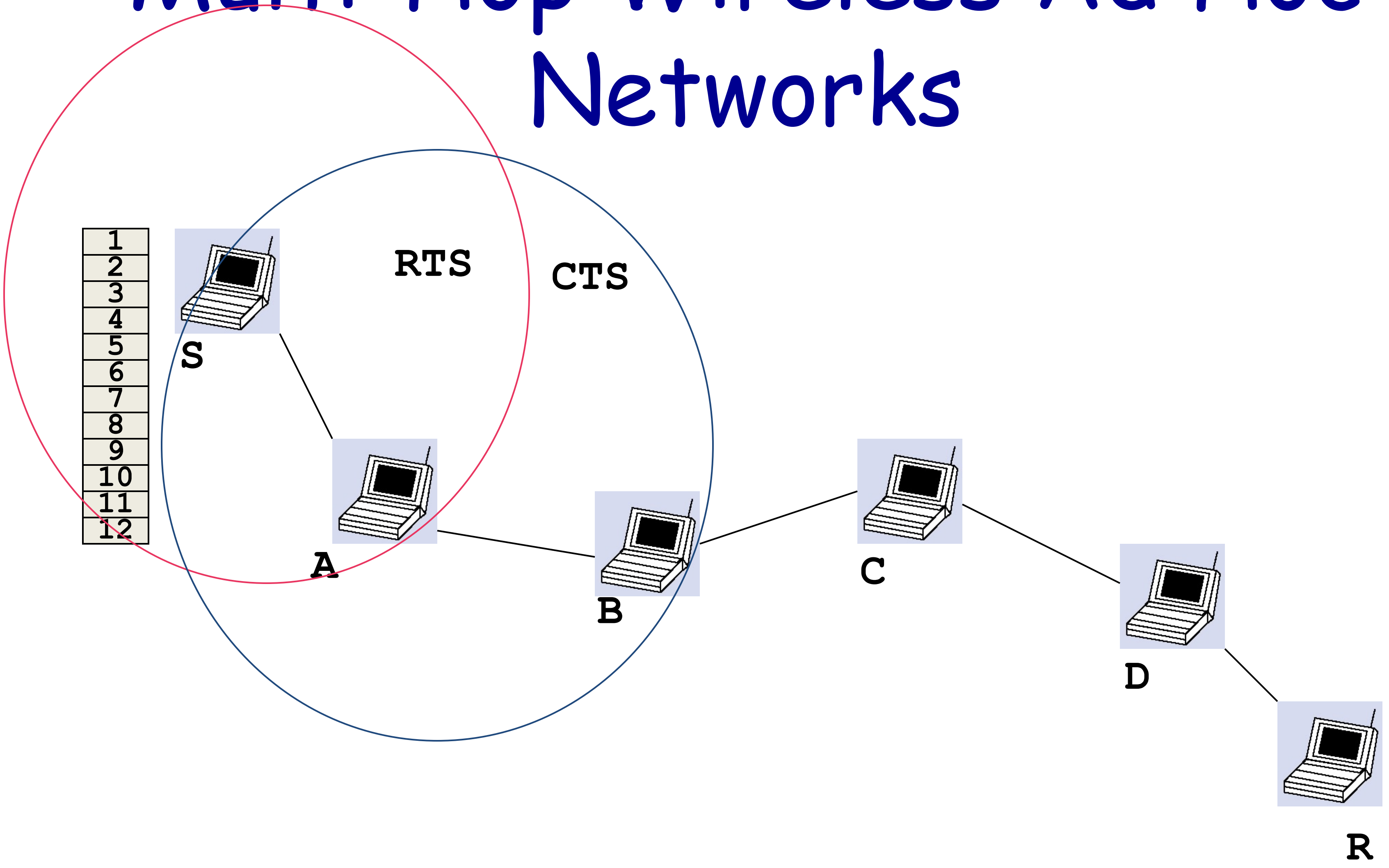
# Multi-Hop Wireless Ad Hoc Networks

Problem 3: LOTS of contention for the channel
- in steady state, all want to send
- need RTS/CTS to resolve contention

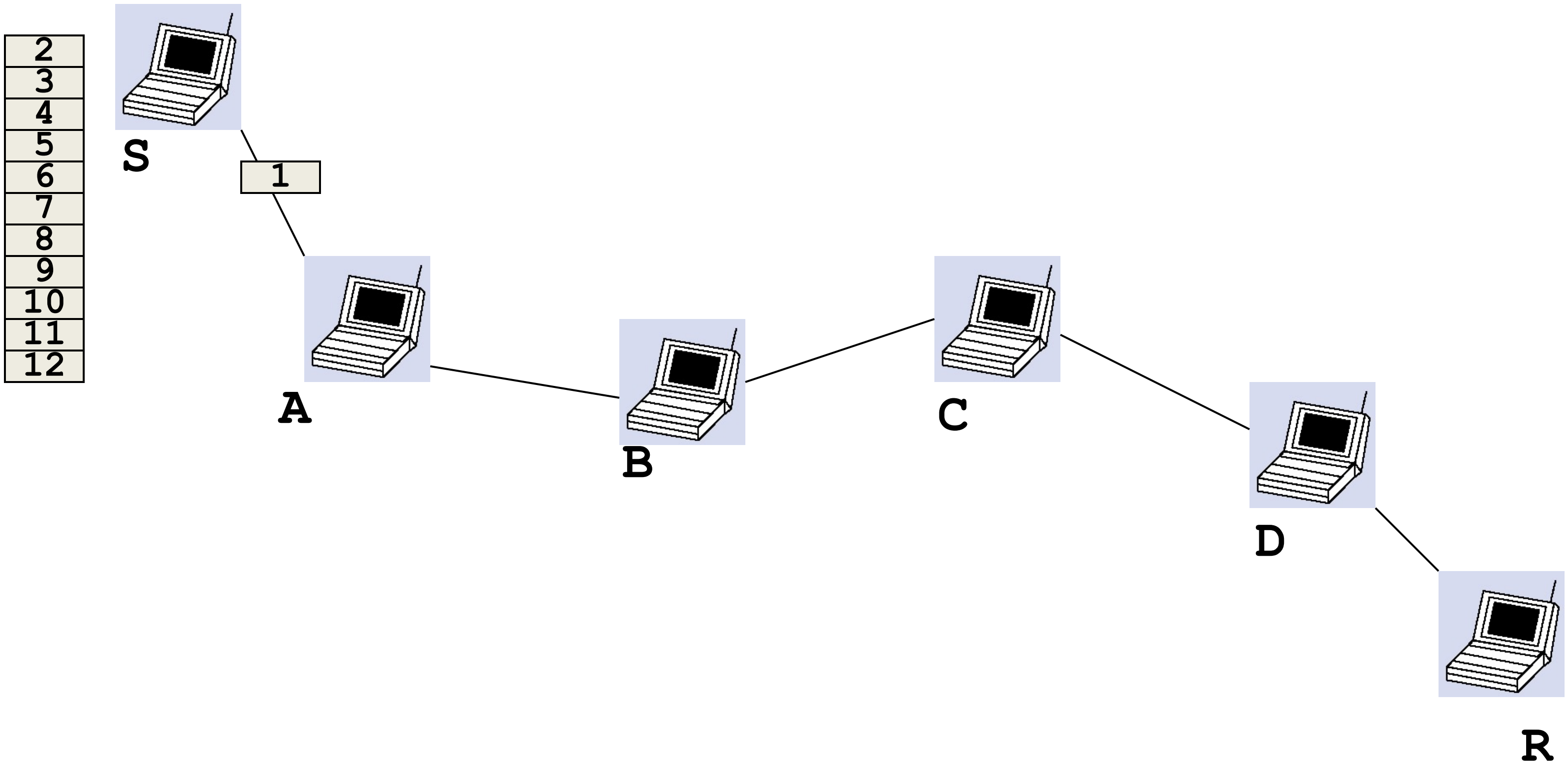


RTS: Request-To-Send
CTS: Clear-To-Send

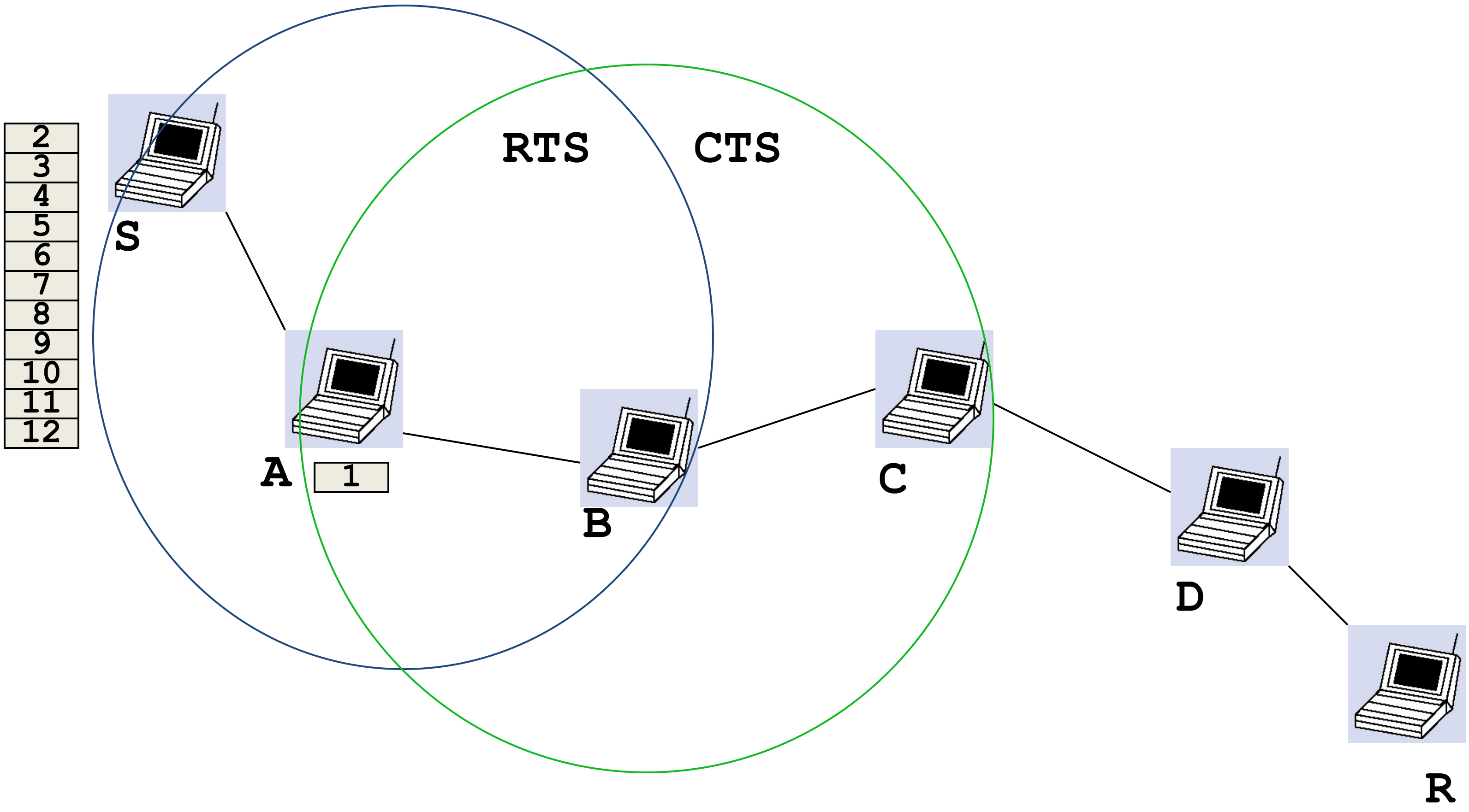
# Multi-Hop Wireless Ad Hoc Networks



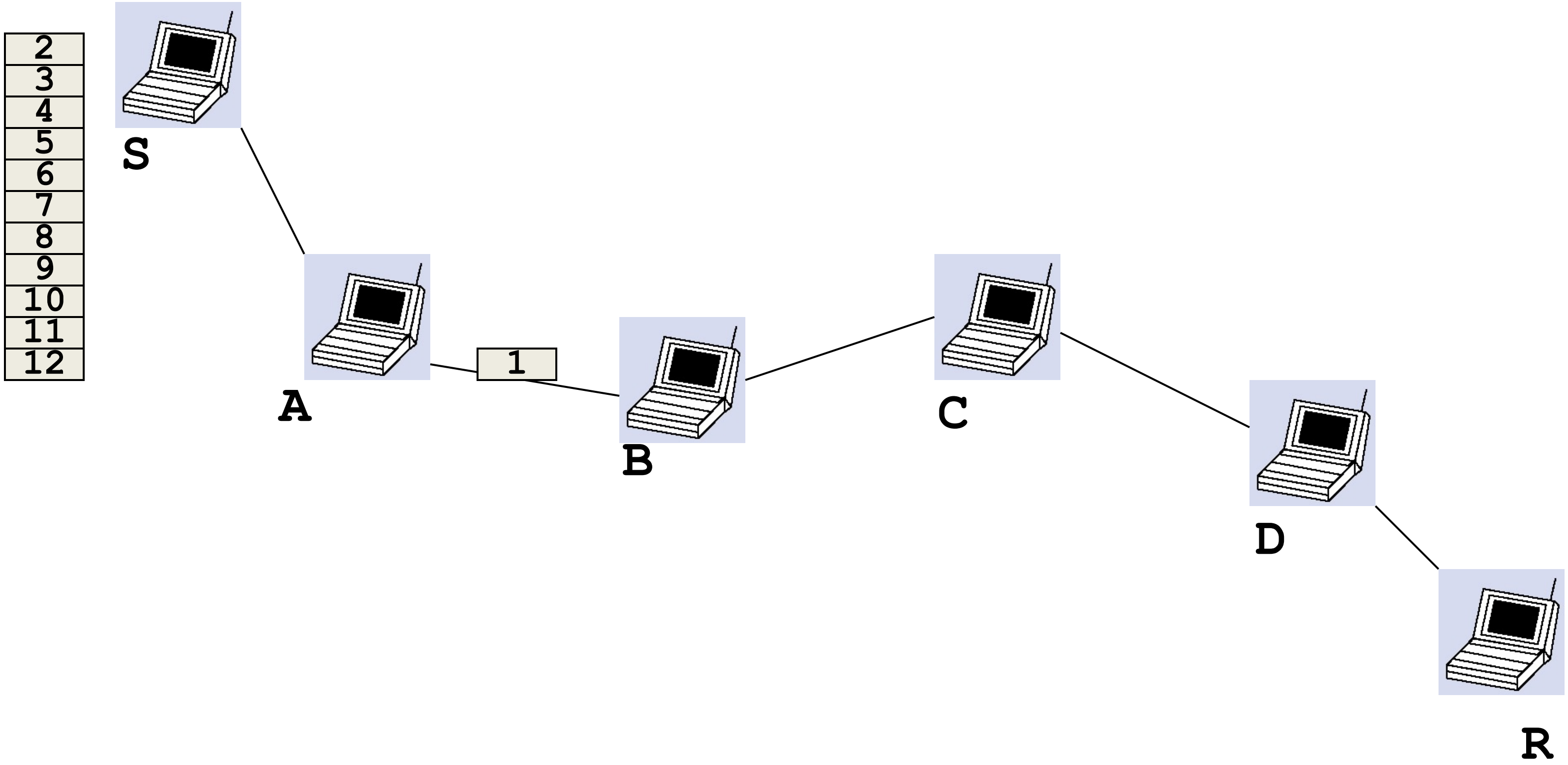
# Multi-Hop Wireless Ad Hoc Networks



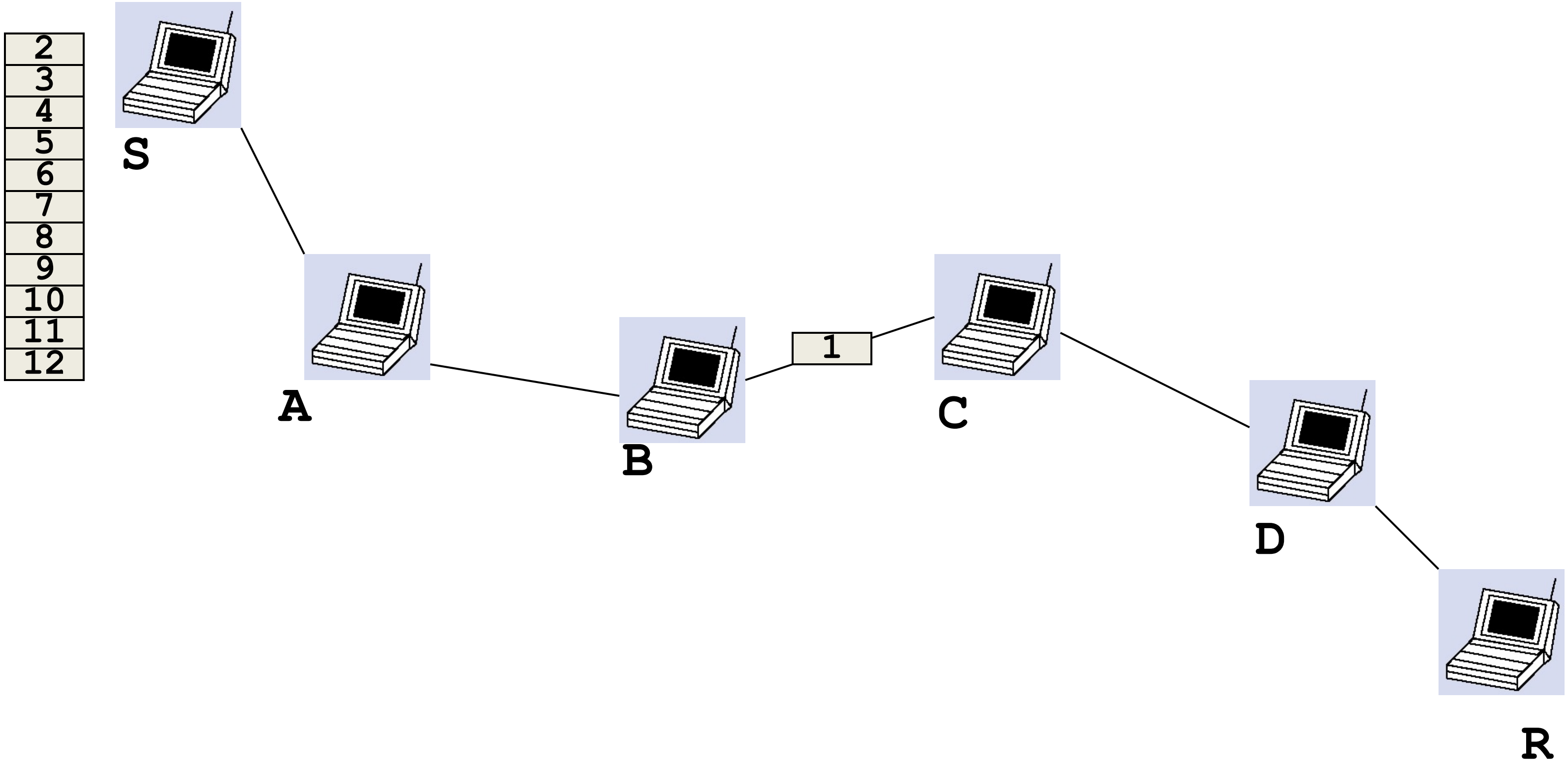
# Multi-Hop Wireless Ad Hoc Networks



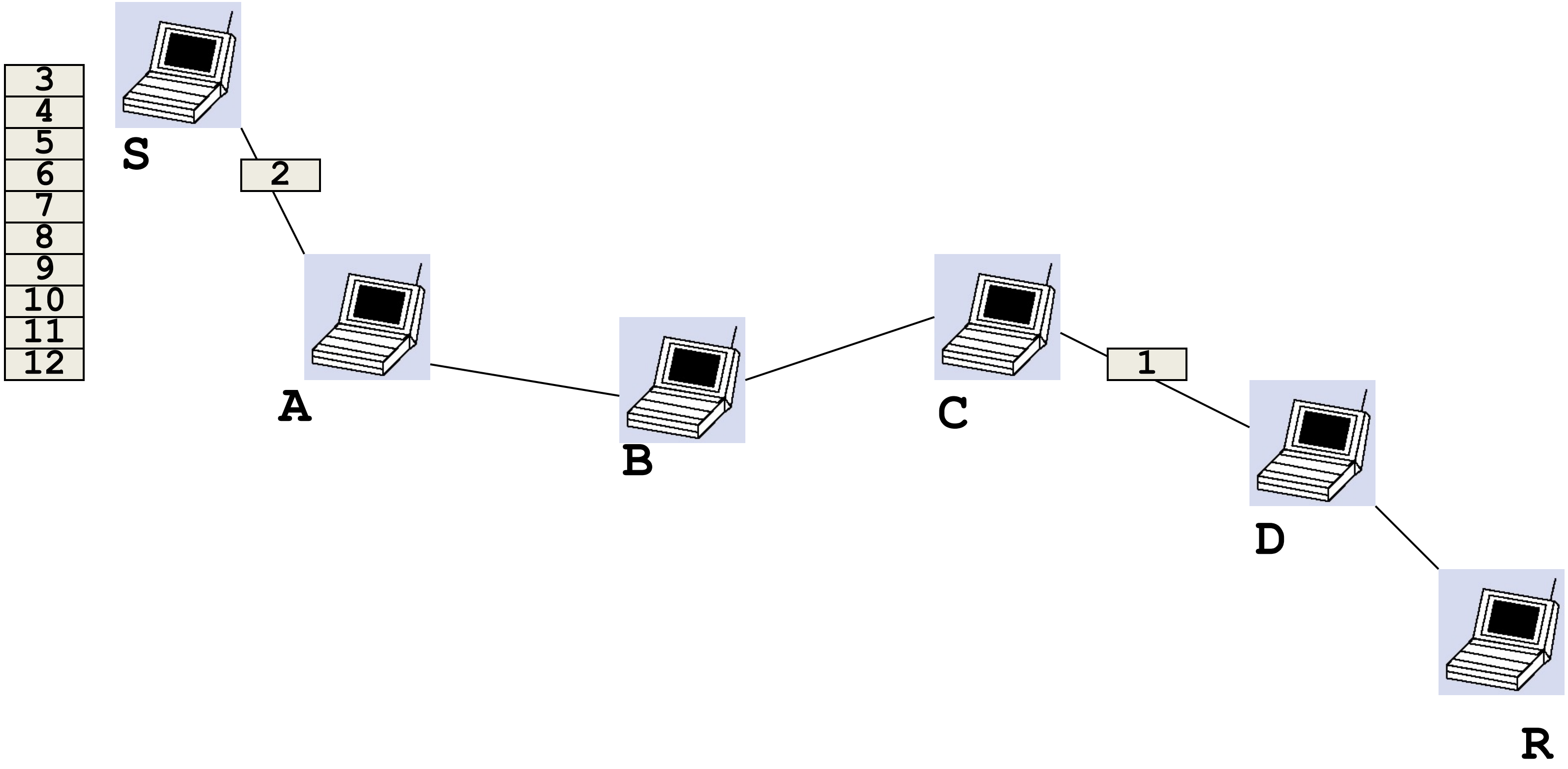
# Multi-Hop Wireless Ad Hoc Networks



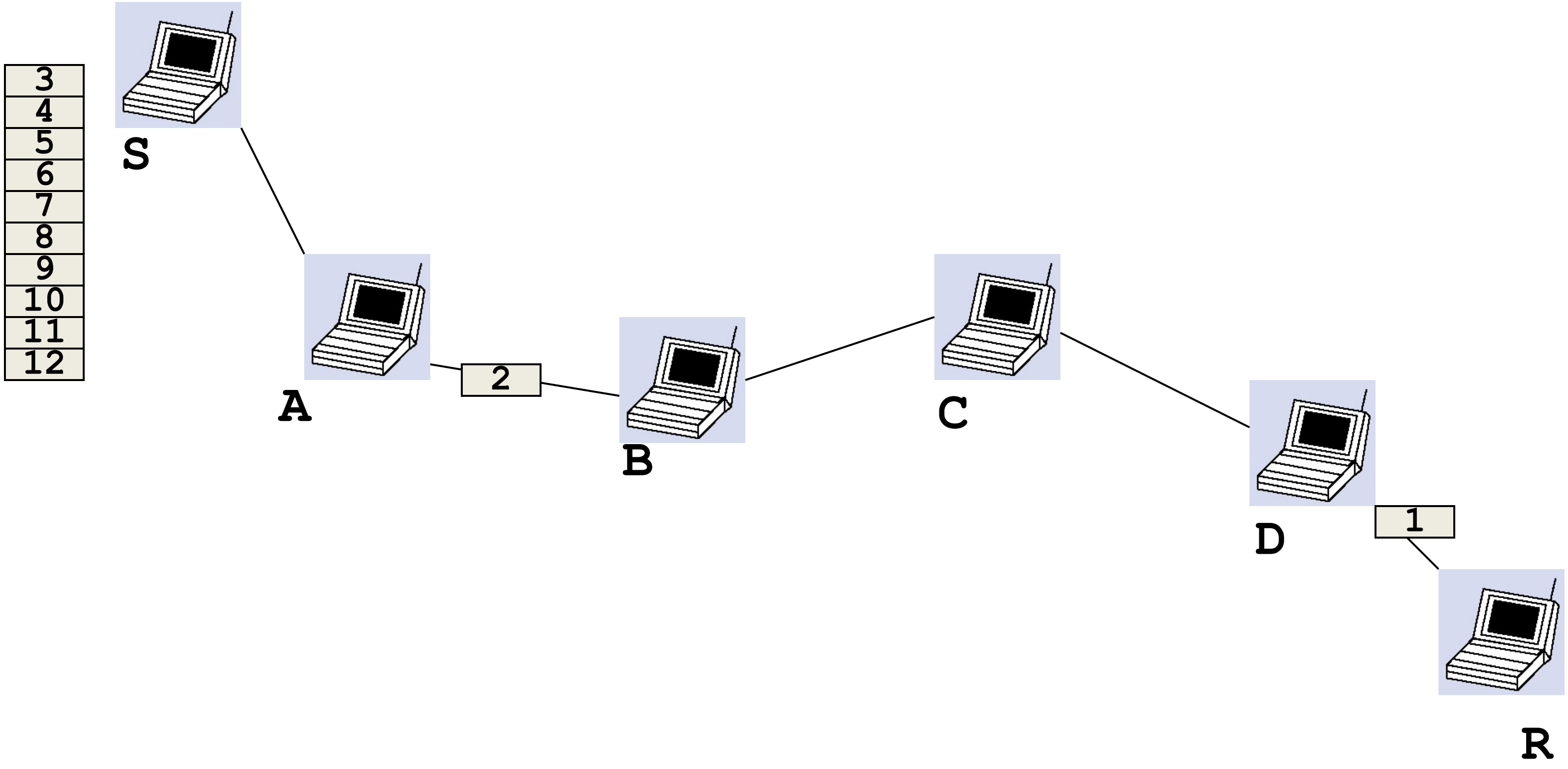
# Multi-Hop Wireless Ad Hoc Networks



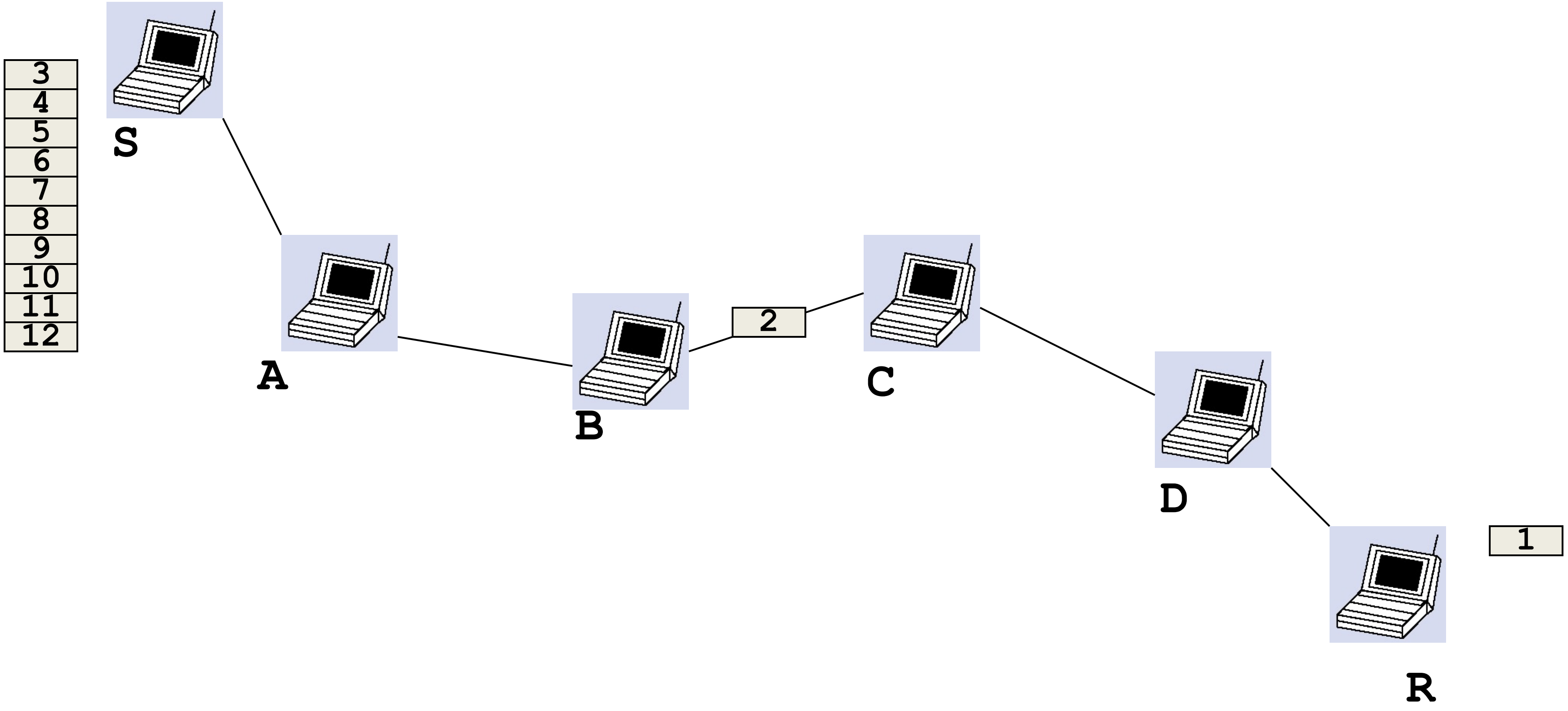
# Multi-Hop Wireless Ad Hoc Networks



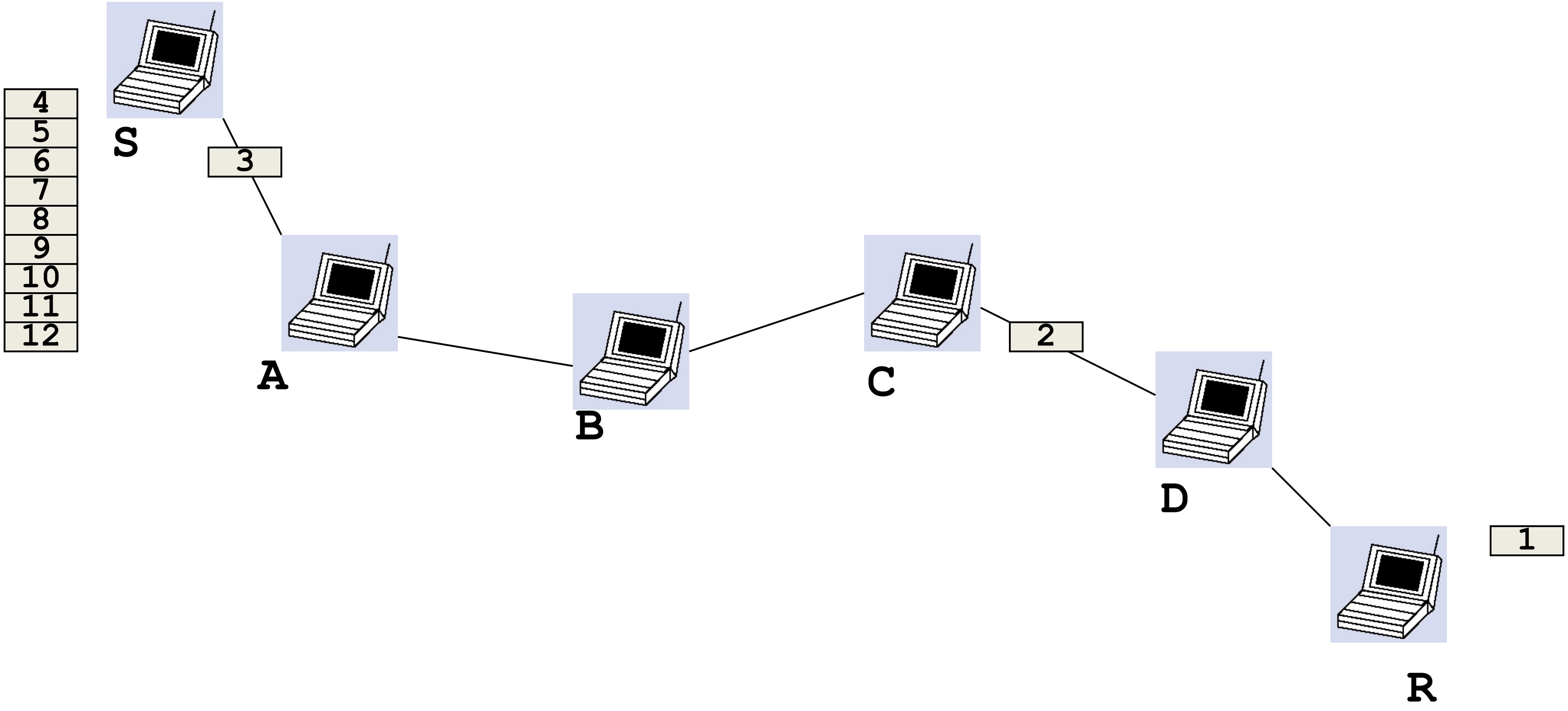
# Multi-Hop Wireless Ad Hoc Networks



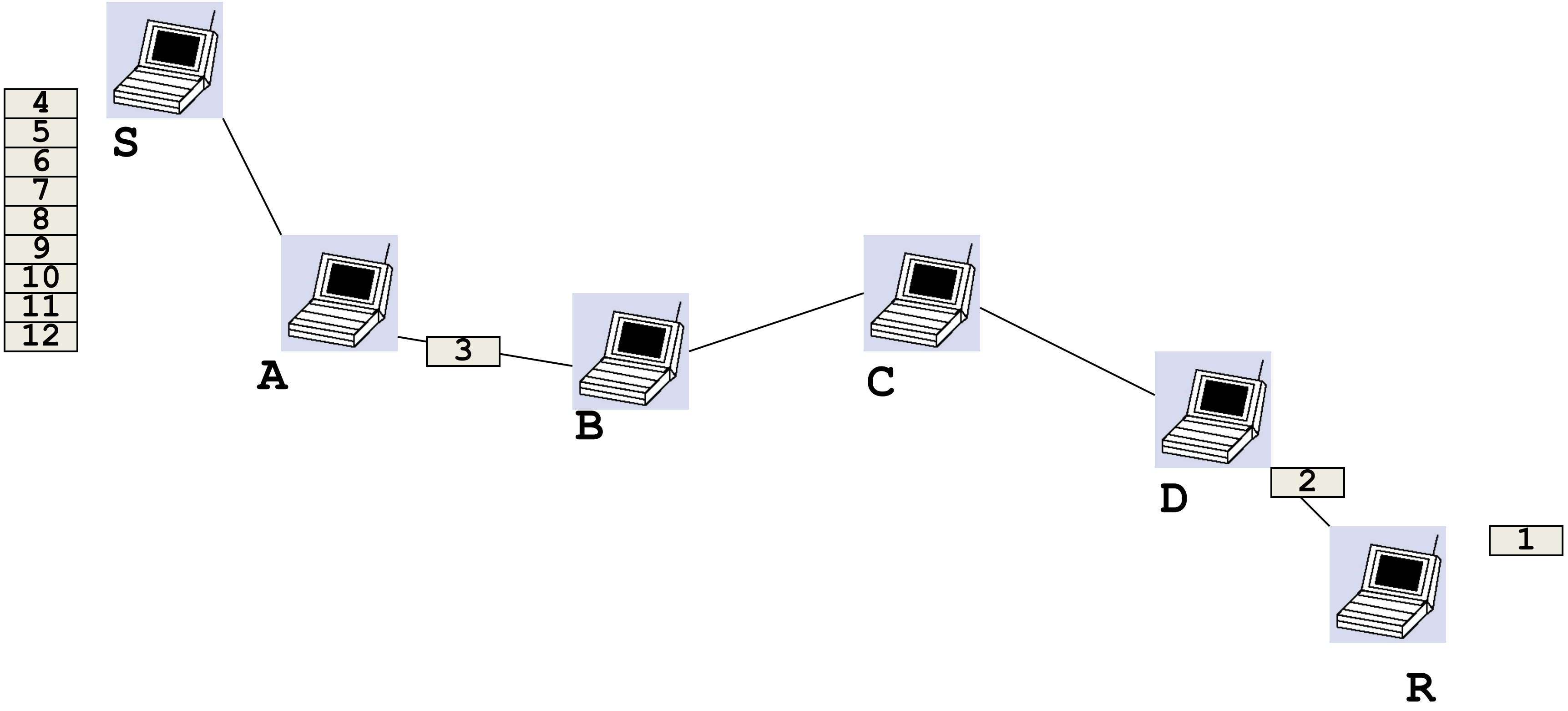
# Multi-Hop Wireless Ad Hoc Networks



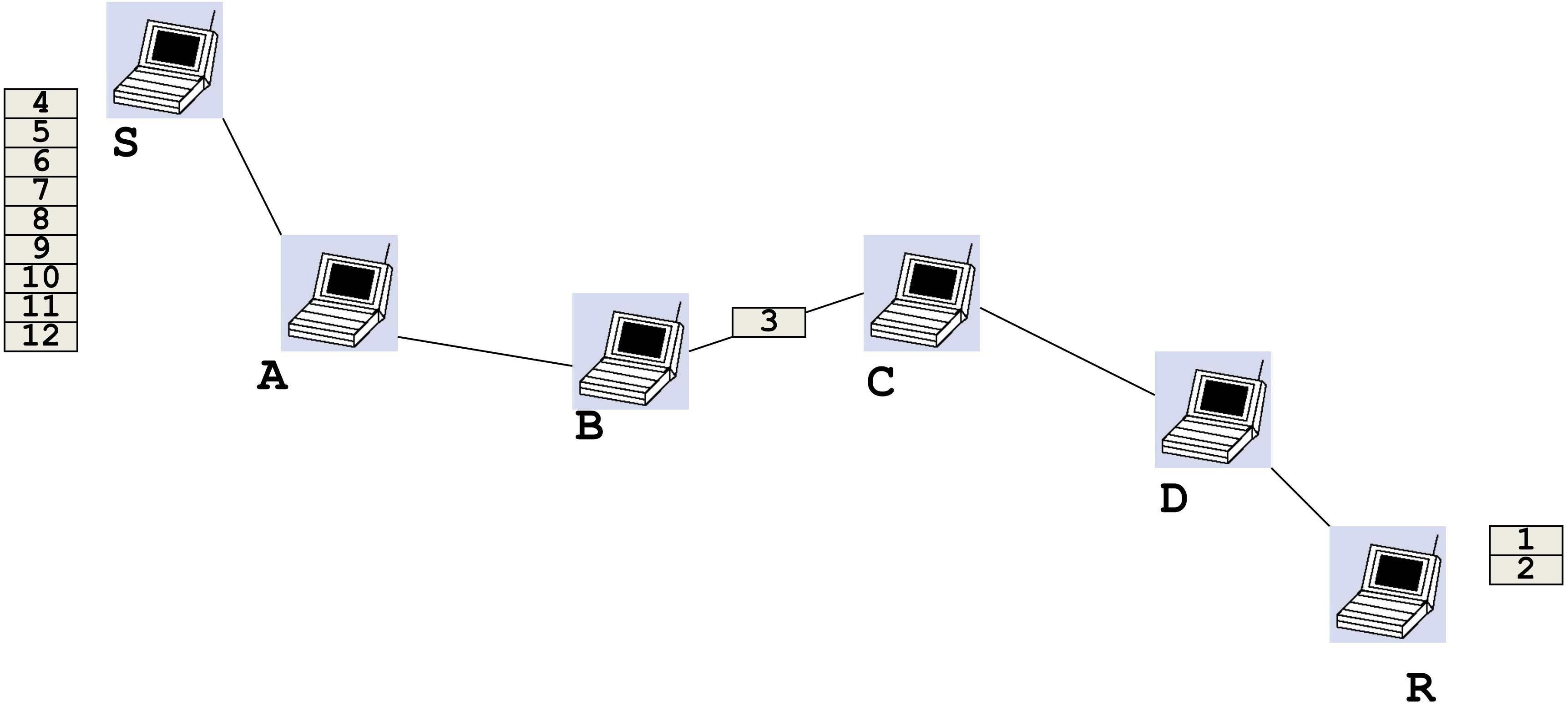
# Multi-Hop Wireless Ad Hoc Networks



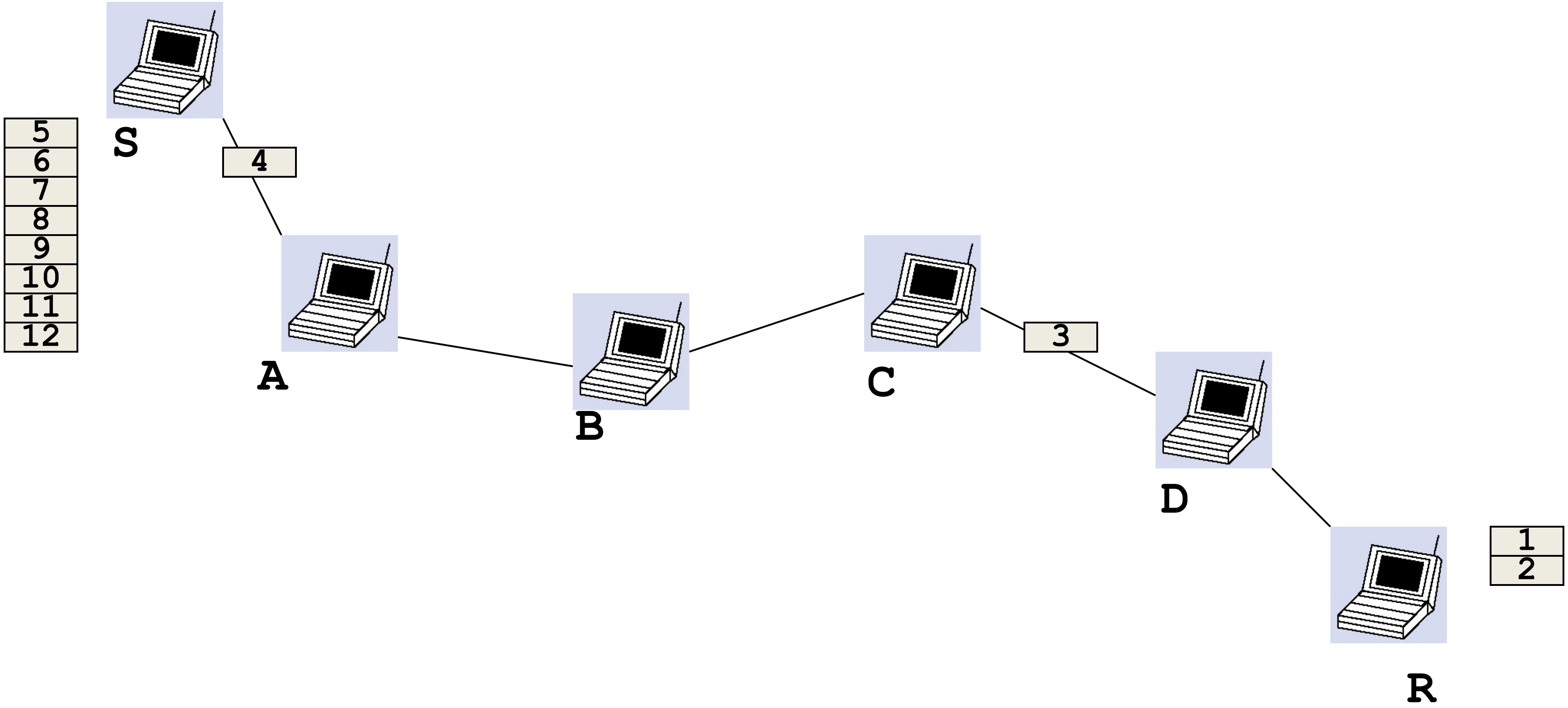
# Multi-Hop Wireless Ad Hoc Networks



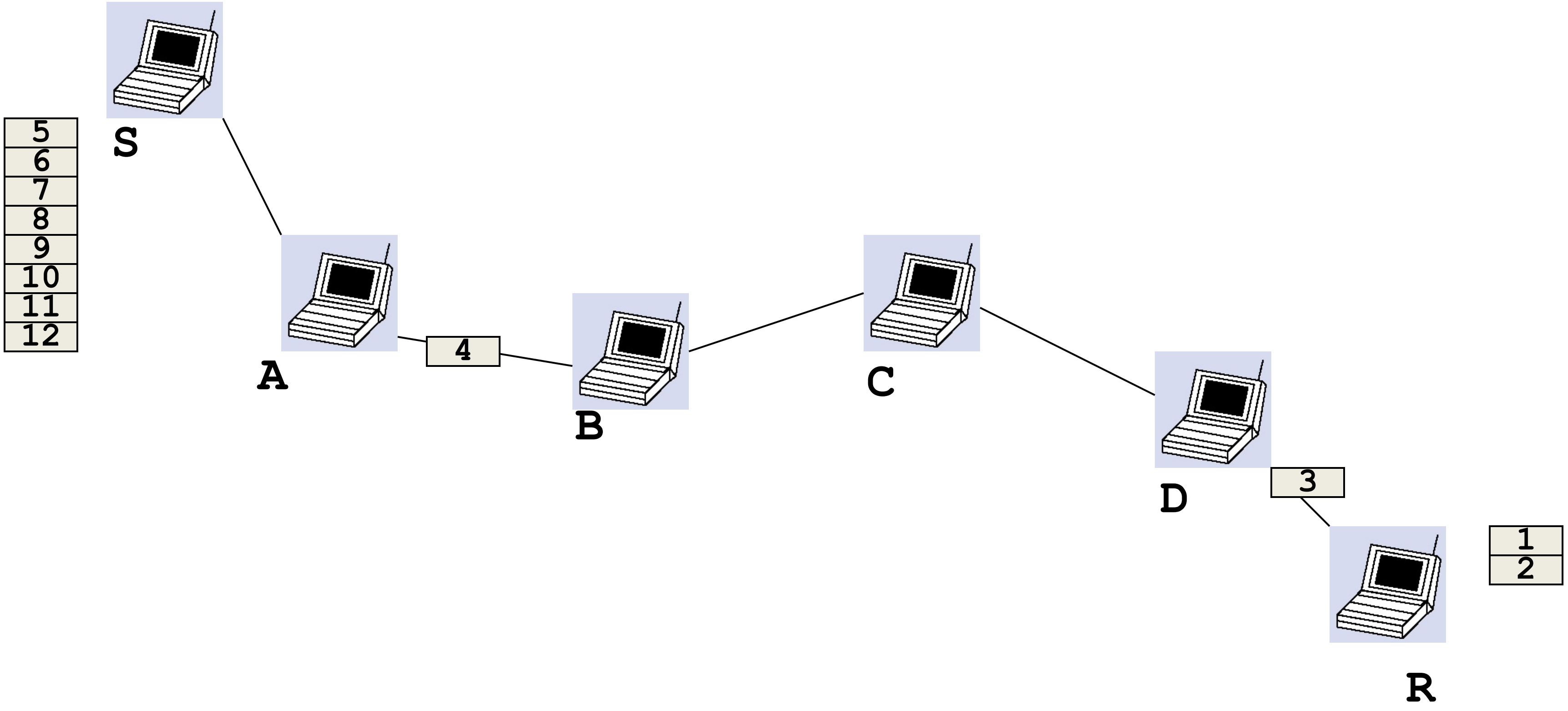
# Multi-Hop Wireless Ad Hoc Networks



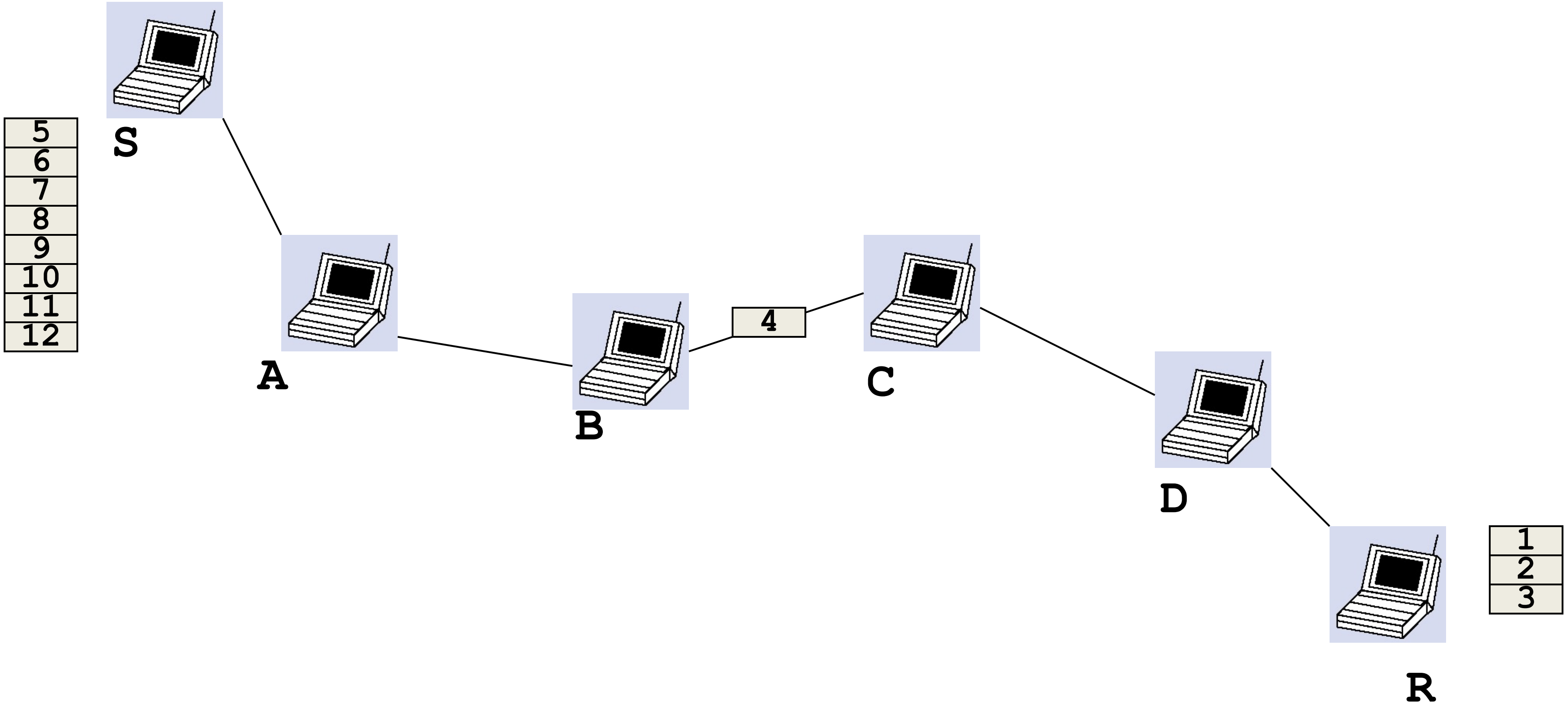
# Multi-Hop Wireless Ad Hoc Networks



# Multi-Hop Wireless Ad Hoc Networks



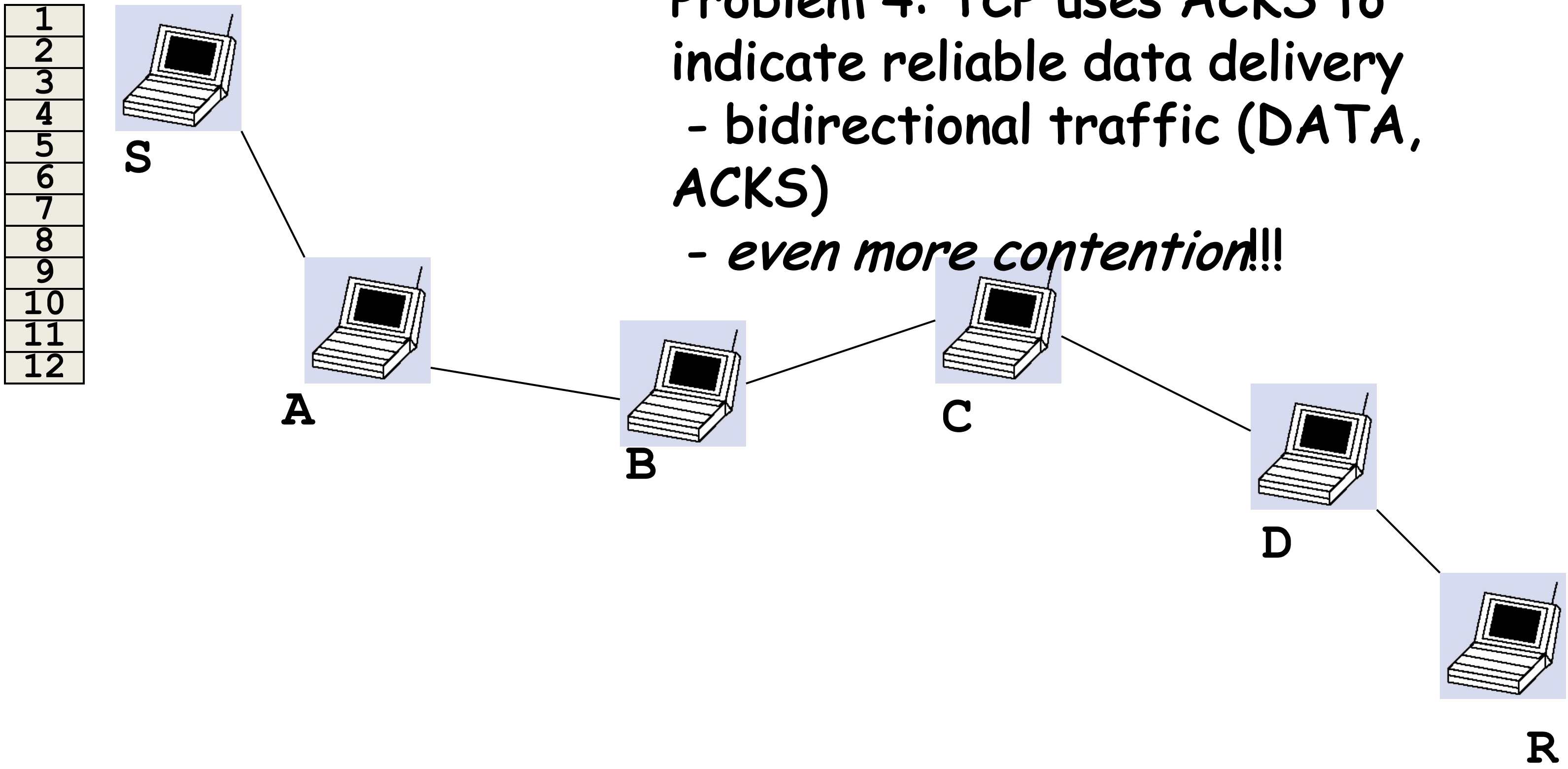
# Multi-Hop Wireless Ad Hoc Networks



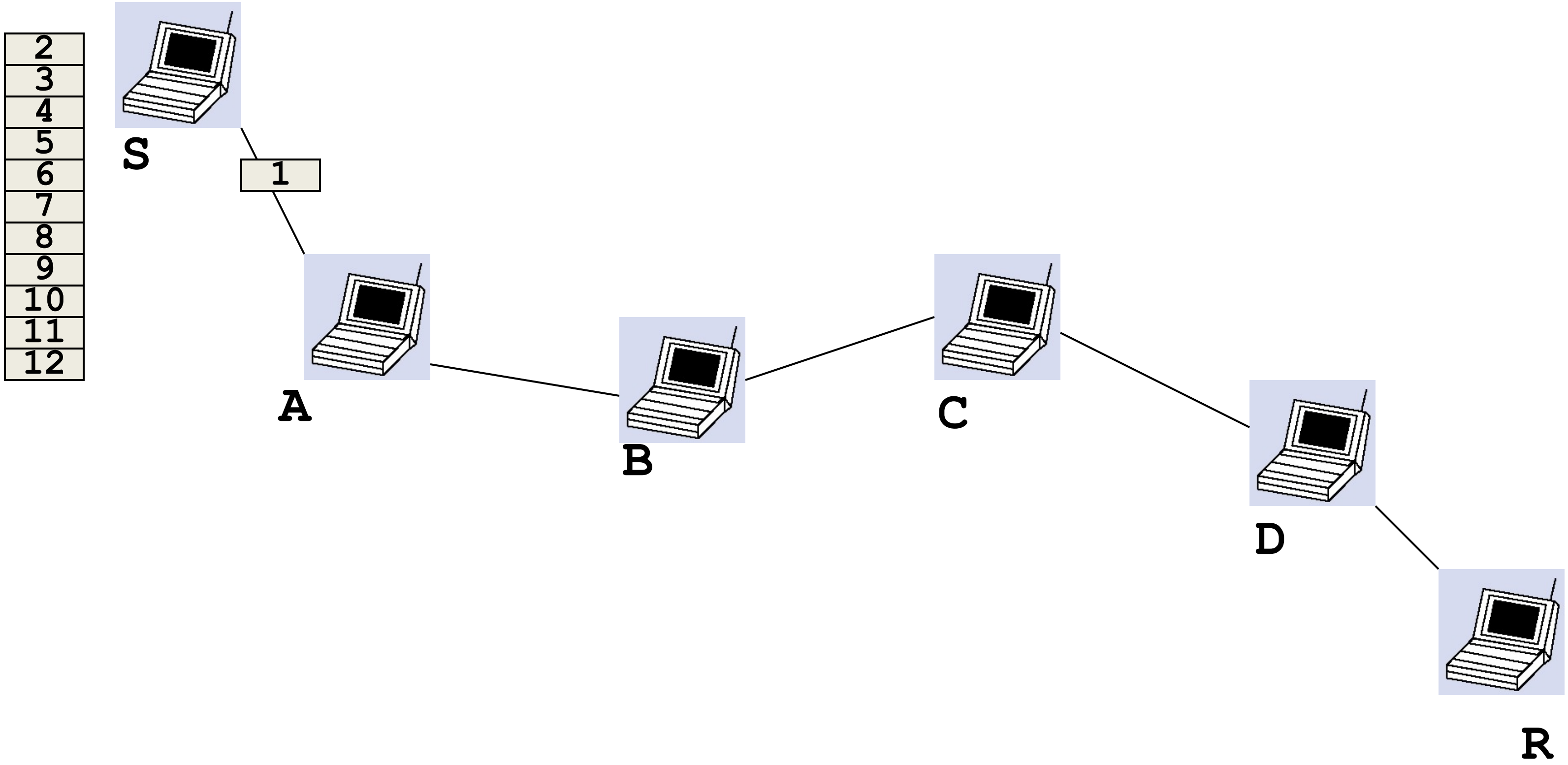
# Multi-Hop Wireless Ad Hoc Networks

Problem 4: TCP uses ACKS to indicate reliable data delivery

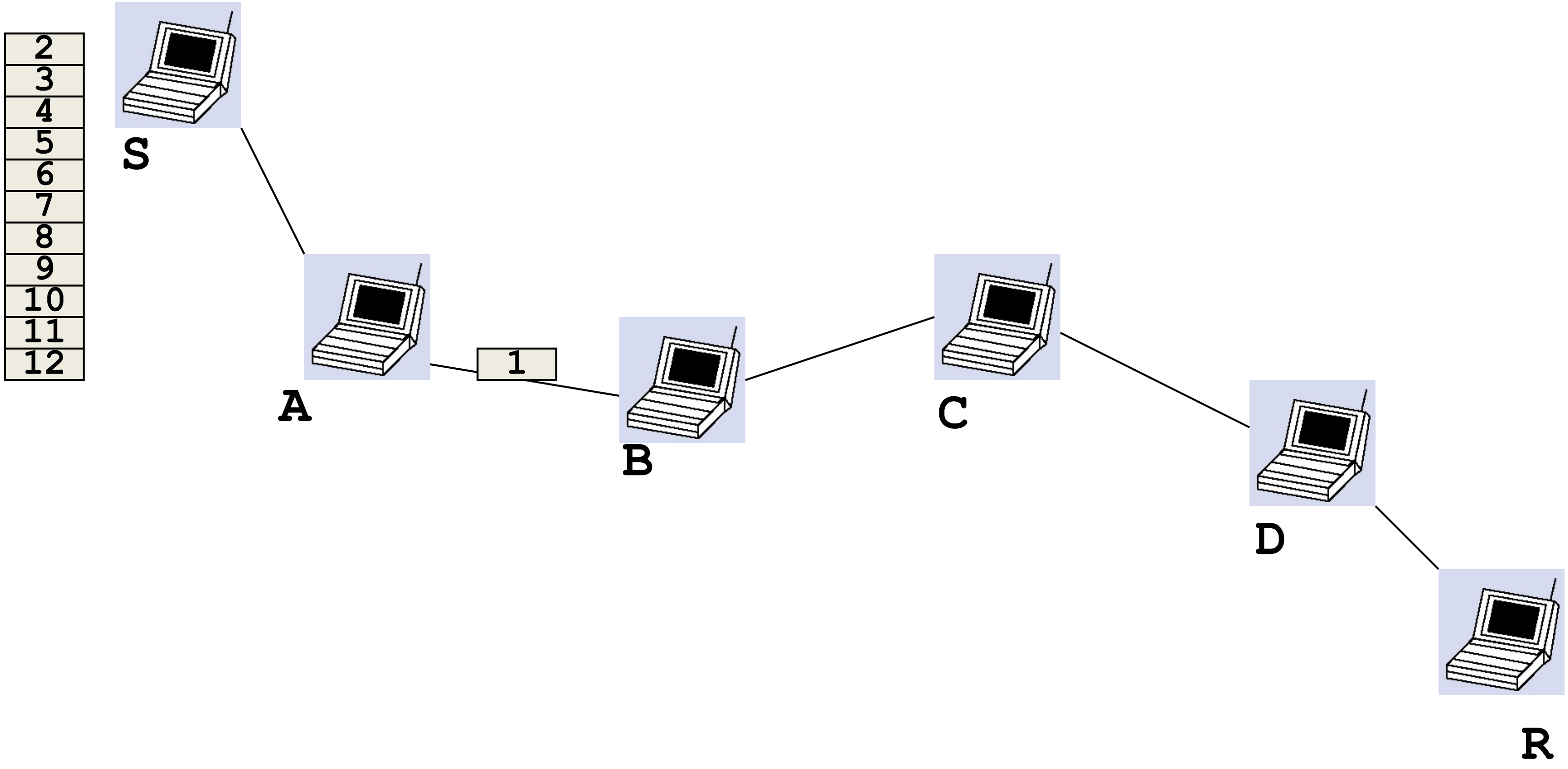
- bidirectional traffic (DATA, ACKS)
- *even more contention*!!!



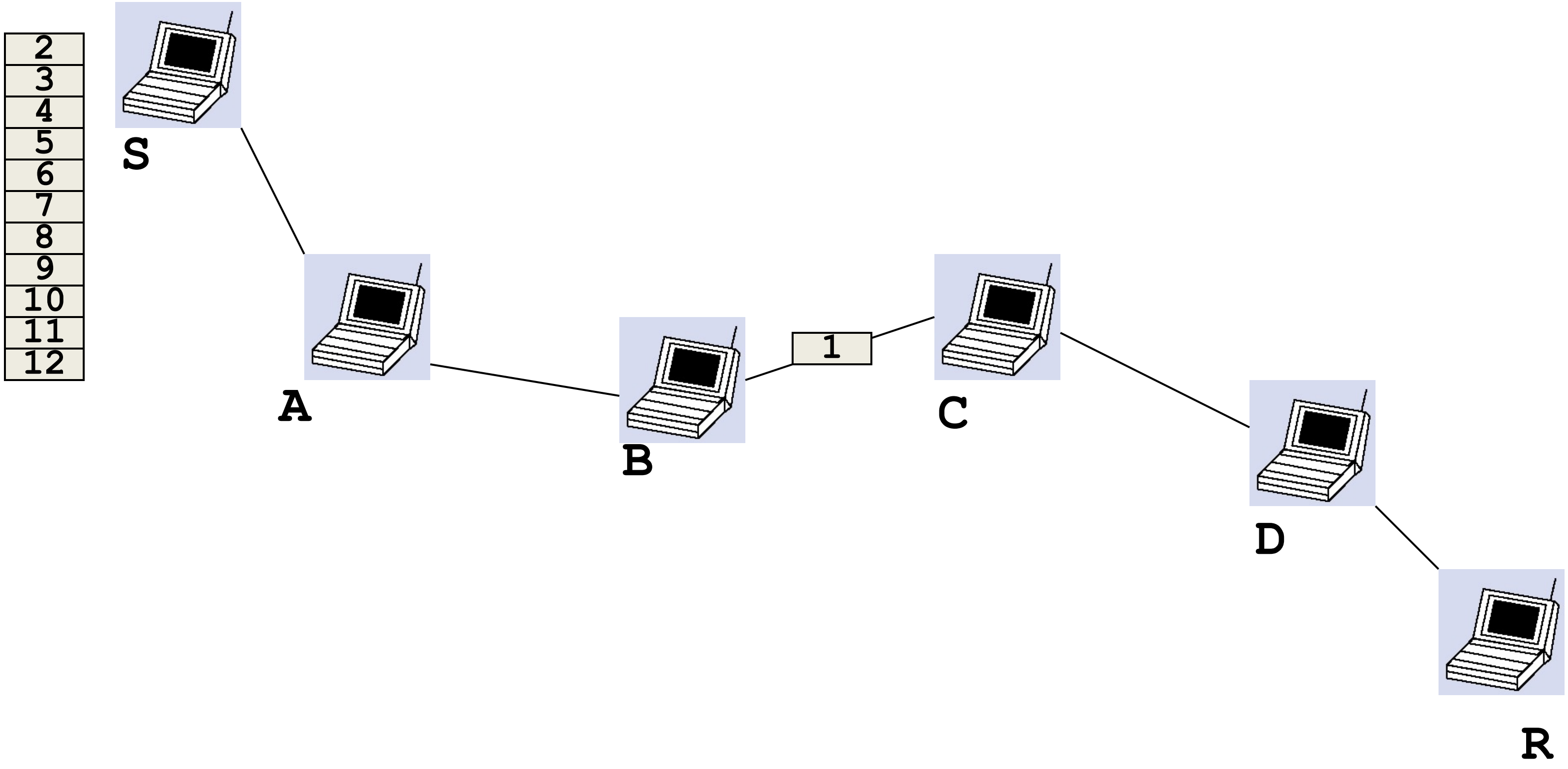
# Multi-Hop Wireless Ad Hoc Networks



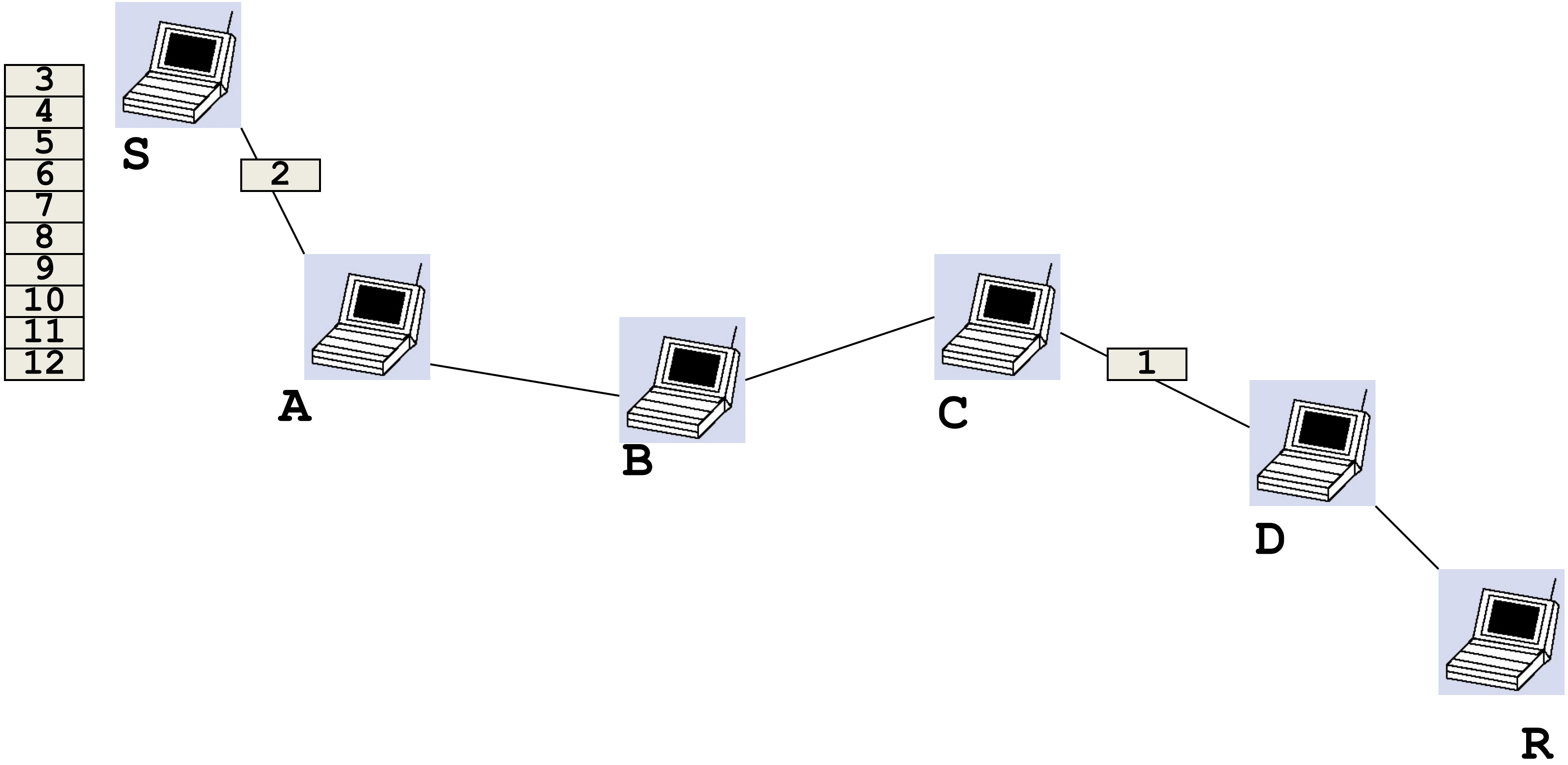
# Multi-Hop Wireless Ad Hoc Networks



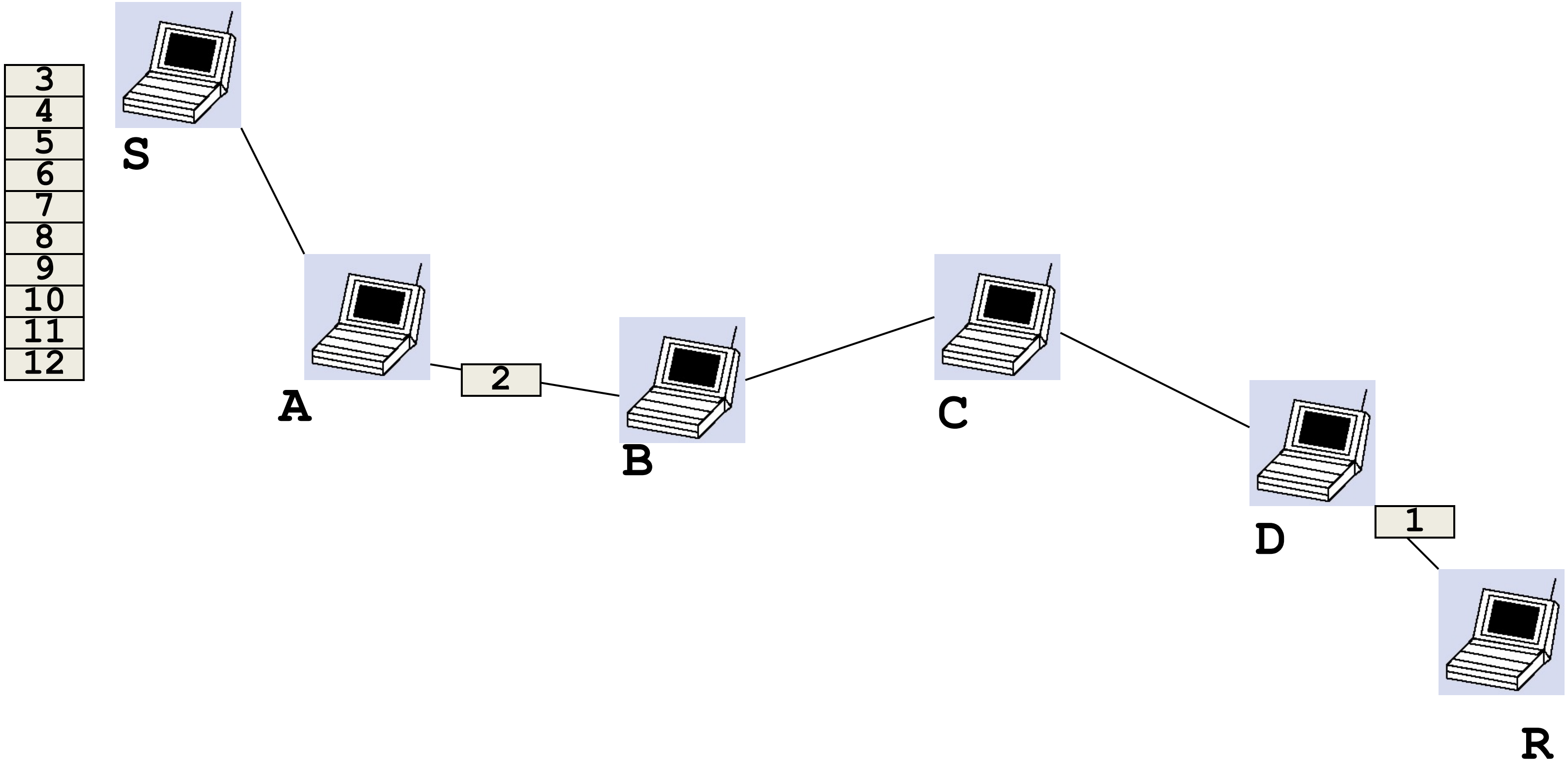
# Multi-Hop Wireless Ad Hoc Networks



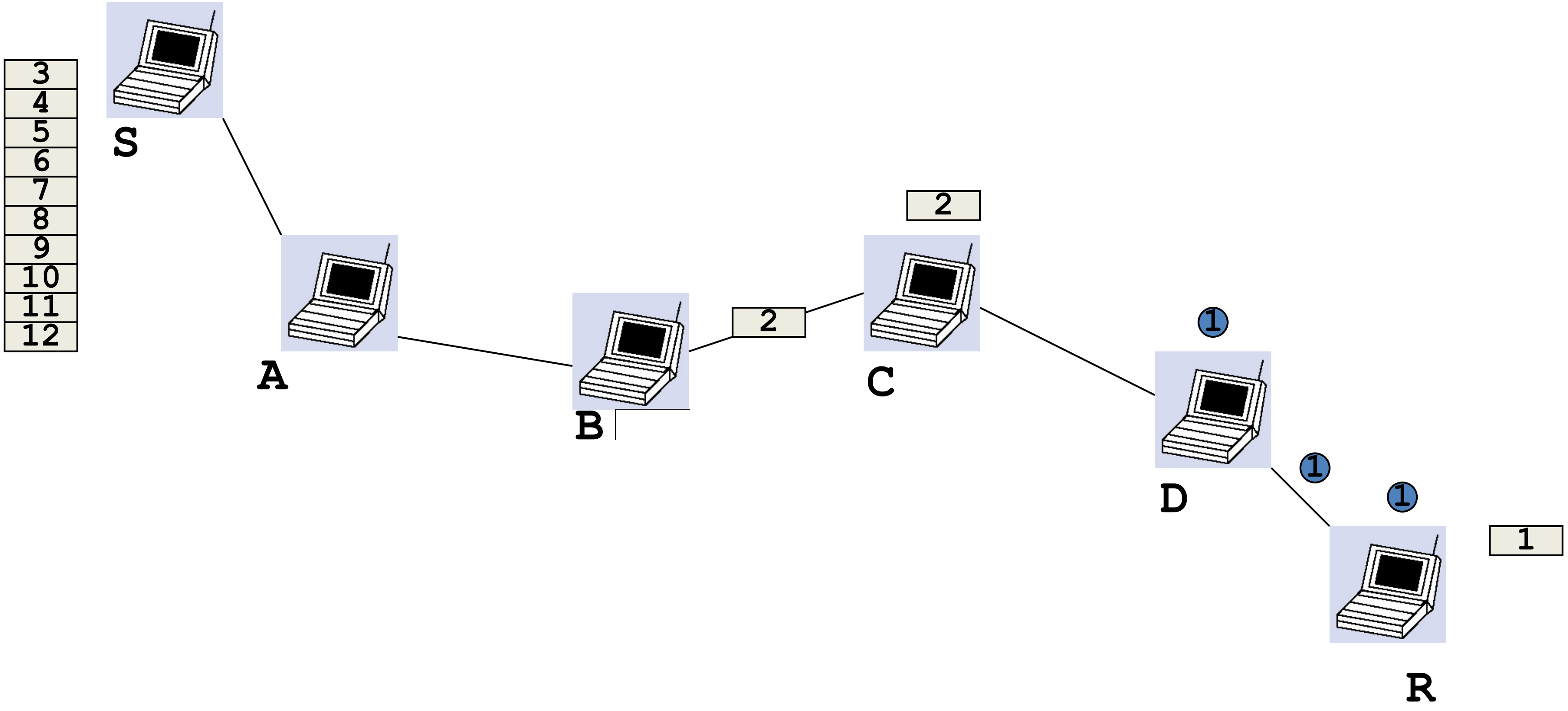
# Multi-Hop Wireless Ad Hoc Networks



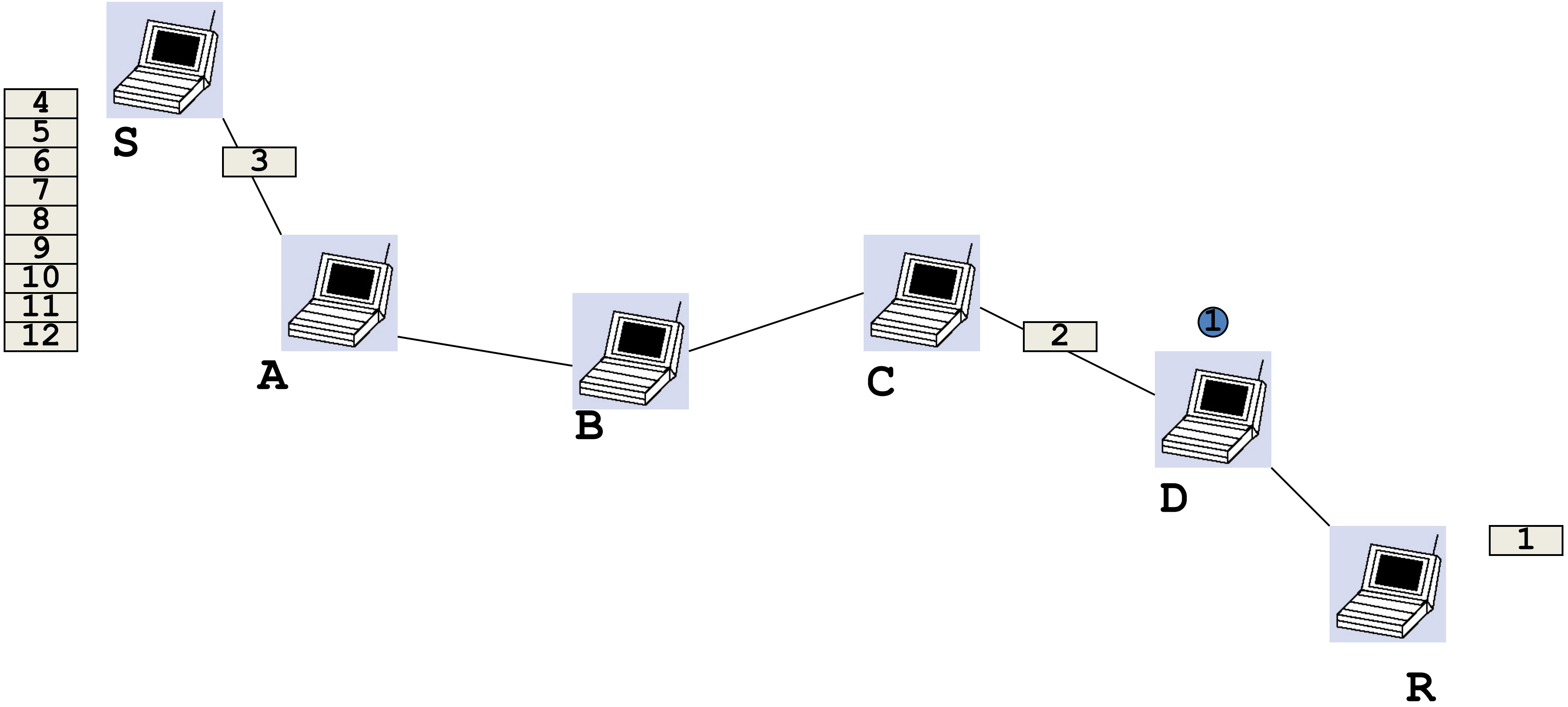
# Multi-Hop Wireless Ad Hoc Networks



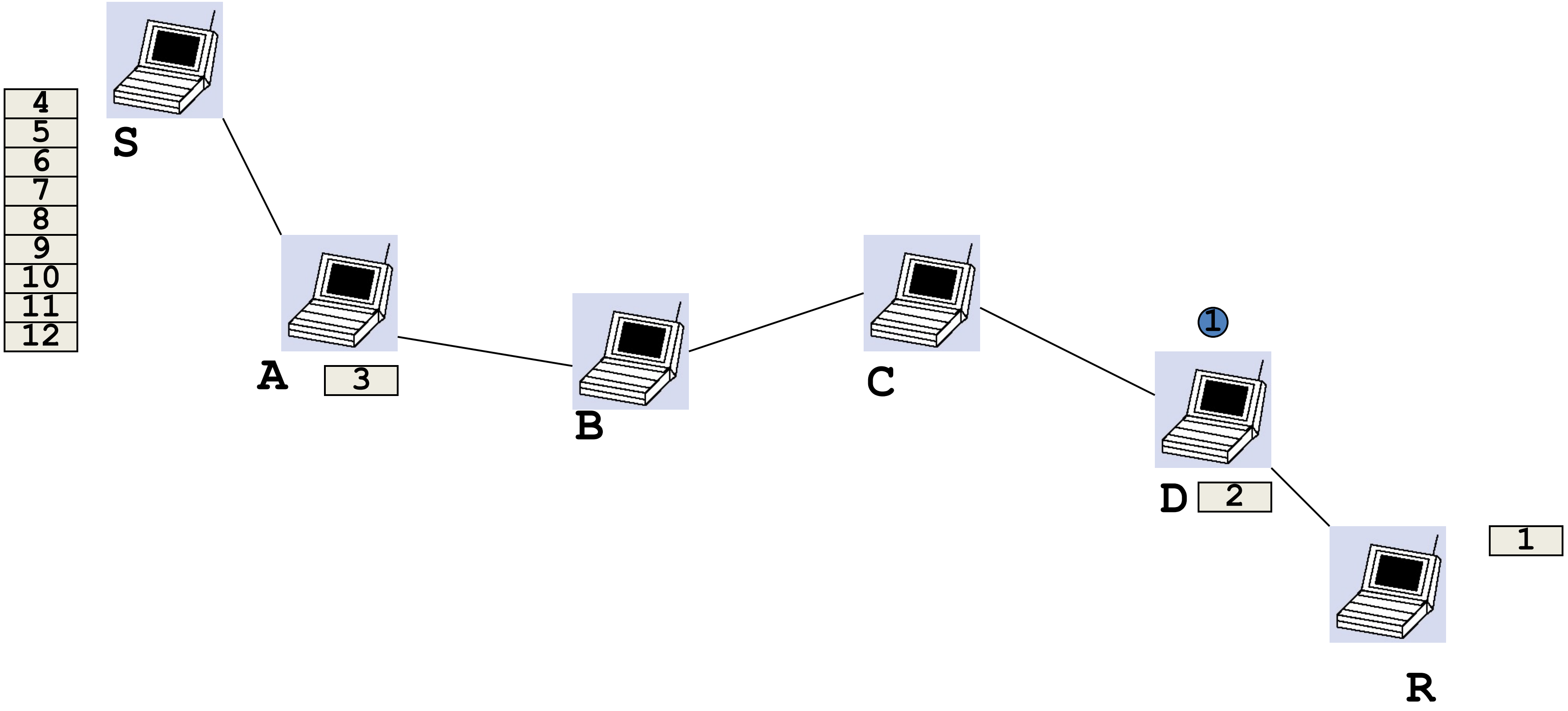
# Multi-Hop Wireless Ad Hoc Networks



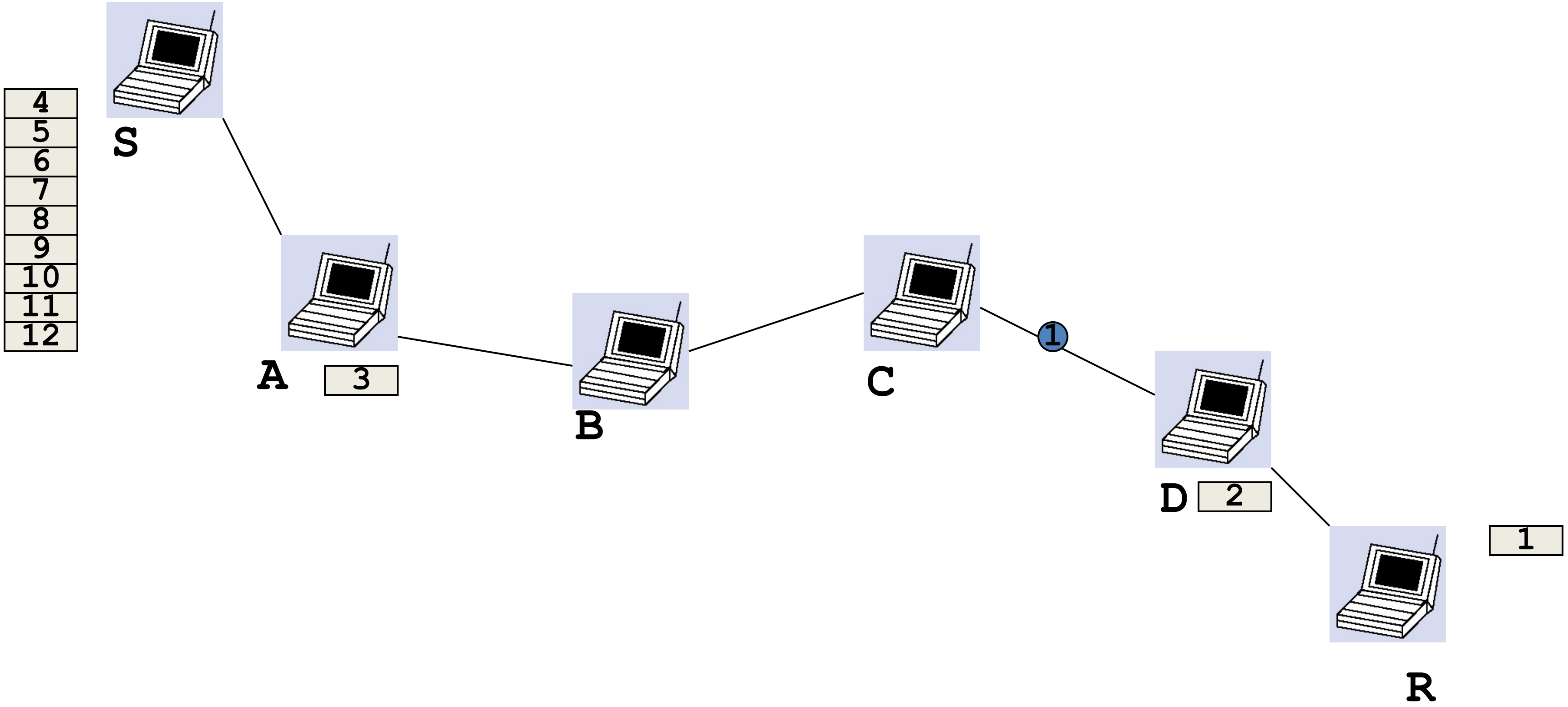
# Multi-Hop Wireless Ad Hoc Networks



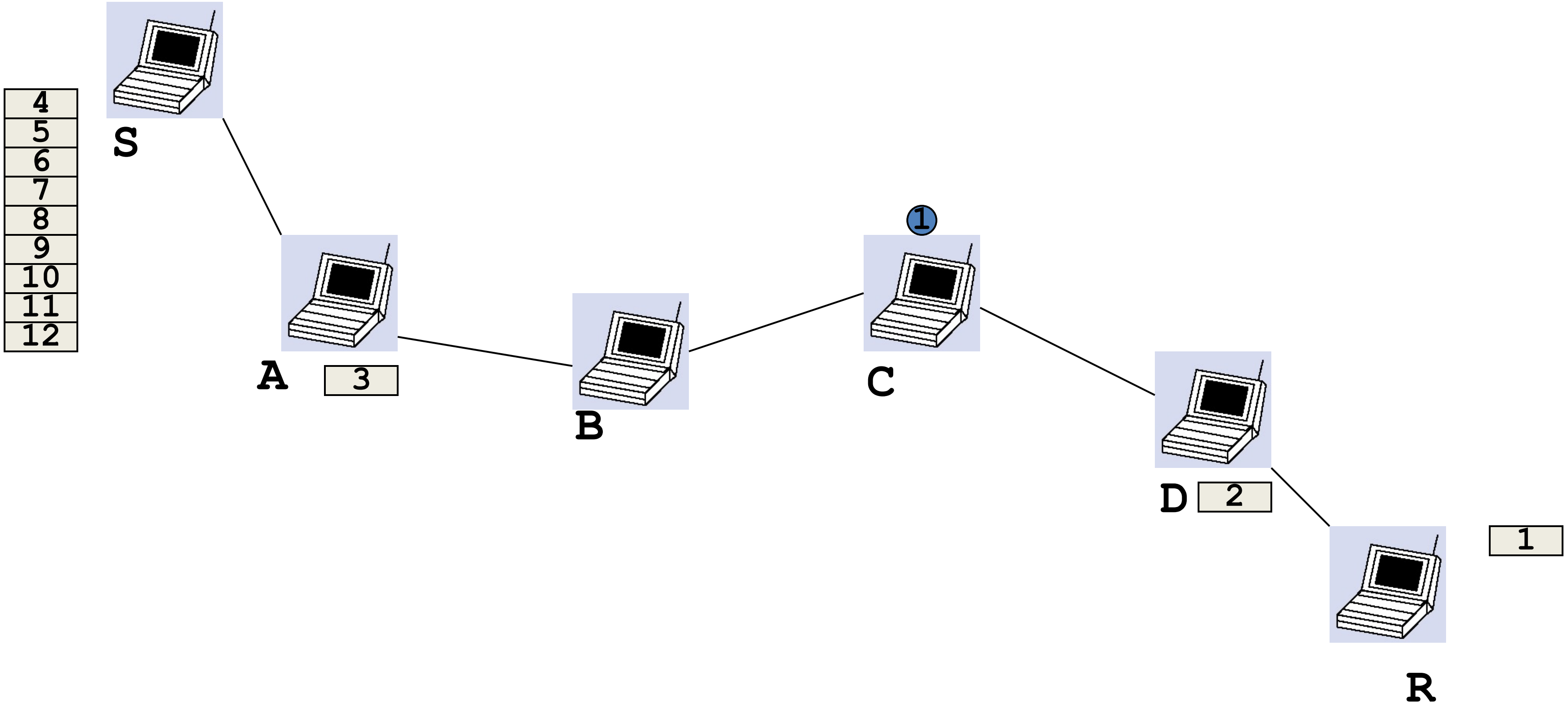
# Multi-Hop Wireless Ad Hoc Networks



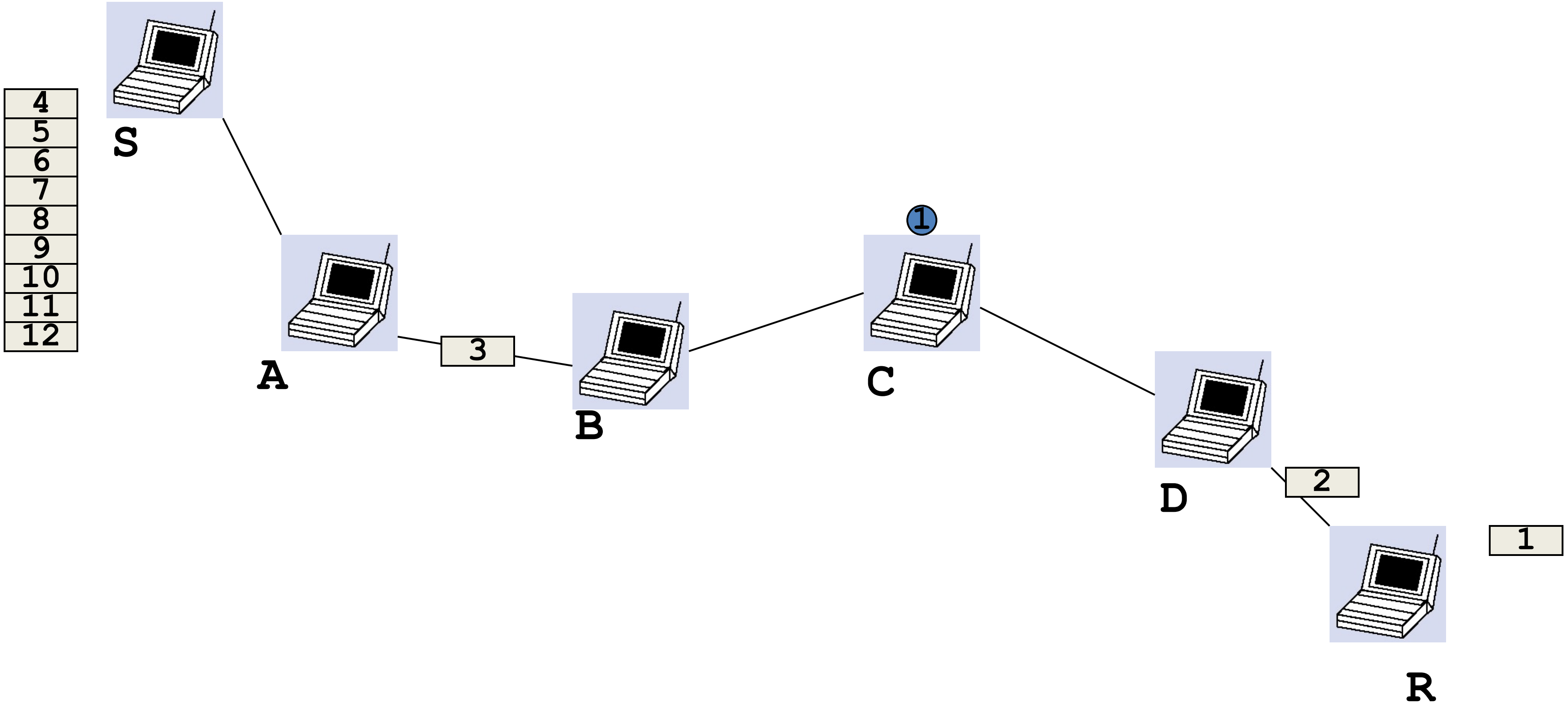
# Multi-Hop Wireless Ad Hoc Networks



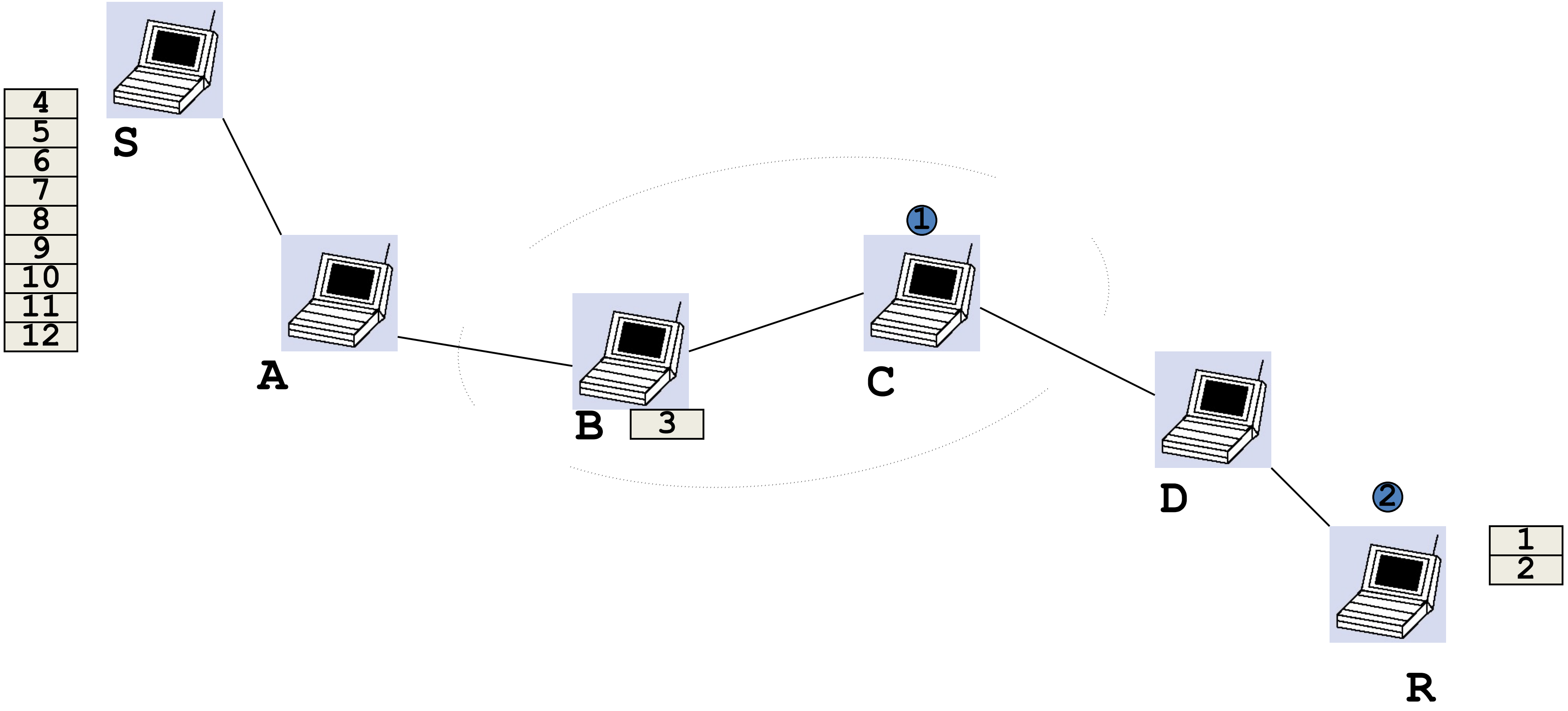
# Multi-Hop Wireless Ad Hoc Networks



# Multi-Hop Wireless Ad Hoc Networks



# Multi-Hop Wireless Ad Hoc Networks



# Security: Concepts and Applications

# Internet's Design: Insecure

- Designed for simplicity
- "On by default" design

- Readily available zombie machines
- Attacks look like normal traffic
- Internet's federated operation obstructs cooperation for diagnosis/mitigation

# Basic Security Properties

- Confidentiality: Concealment of information or resources
- Authenticity: Identification & assurance of origin of info
- Integrity: Trustworthiness of data/resources; preventing improper/unauthorized changes
- Availability: Ability to use desired information/resource
- Non-repudiation: Offer of evidence that a party indeed is sender or a receiver of certain information
- Access control: Facilities to determine and enforce who is allowed access to what resources (host, software, network, …)

# Security protocols at many layers

- Application layer
  - E-mail: PGP, using a web-of-trust
  - Web: HTTP-S, using a certificate hierarchy
- Transport layer
  - Transport Layer Security/ Secure Socket Layer
- Network layer
  - IP Sec
- Network infrastructure
  - DNS-Sec and BGP-Sec

# Symmetric vs. Asymmetric Crypto
## *a.k.a.* Secret vs. Public Key Crypto

- Symmetric crypto (all crypto pre 1970s)
  - Sender and recipient share a common key
  - All classical encryption algorithms are private-key
  - Dual use: confidentiality or authentication/integrity
    - Encryption vs. msg authentication code (MAC)

- Public-key crypto
  - (Public, private) key associated w/ea. entity ("Alice")
  - Anybody can encrypt to Alice, anybody can verify Alice's message
  - Only Alice can decrypt, only Alice can "sign"
  - Developed to address "key distribution" problem and "digital signatures" (w/o prior establishment)

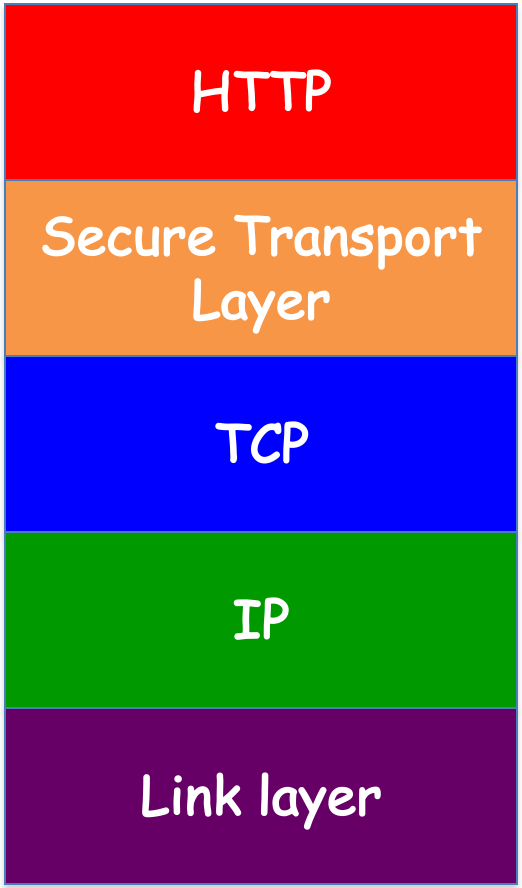
# Why still both?

- Symmetric Pros and Cons
  - Simple and very fast (1000-10000x faster than asymmetric)
  - Must agree/distribute the key beforehand
  - AES/CBC (256-bit) → 80 MB/s (*for 2048 bits, .003 ms*)
- Public Key Pros and Cons
  - Easier key pre-distro.: "Public Key Infrastructure" (PKI)
  - Much slower
  - 2048-RSA → 6.1ms Decrypt, 0.16ms Encrypt
- Common "engineering" approach:
  - Best of both worlds via "hybrid" scheme: Use public key to distribute a new random "session" key b/w sender and recipient, then symmetric crypto for remainder of session

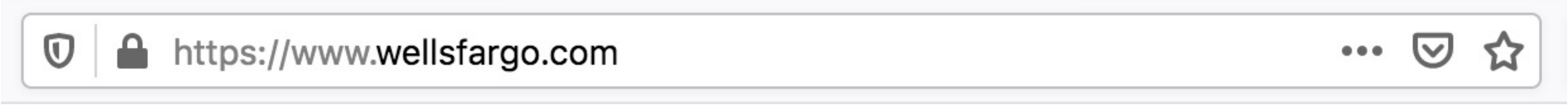
# HTTP Security

# HTTP-S: Securing HTTP

- HTTP sits on top of secure channel (SSL/TLS)
  - https:// vs. http://
  - TCP port 443 vs. 80
- All (HTTP) bytes encrypted and authenticated
  - No change to HTTP itself!
- Where to get the key???



# Learning a Valid Public Key

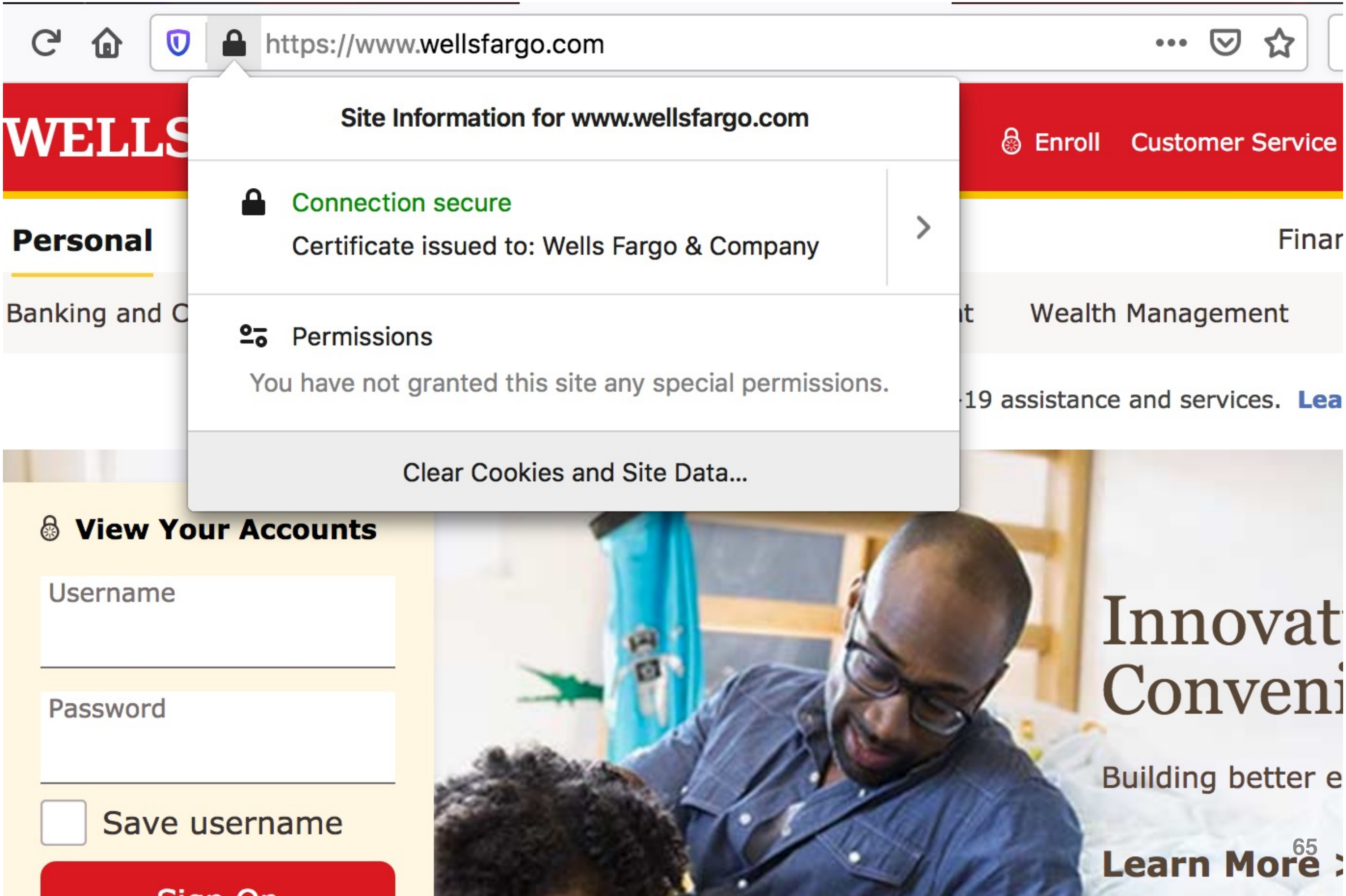

https://www.wellsfargo.com

- What is that lock?
  - Securely binds domain name to public key (PK)
    - If PK is authenticated, then any message signed by that PK cannot be forged by non-authorized party
  - Believable only if you trust the attesting body
    - Bootstrapping problem: Who to trust, and how to tell if this message is actually from them?

# Hierarchical Public Key Infrastructure

- Public key certificate
  - Binding between identity and a public key
  - "Identity" is, for example, a domain name
  - Digital signature to ensure integrity
- Certificate authority
  - Issues public key certificates and verifies identities
  - Trusted parties (e.g., VeriSign, GoDaddy, Comodo)
  - Preconfigured certificates in Web browsers

# Public Key Certificate



https://www.wellsfargo.com

Site Information for www.wellsfargo.com

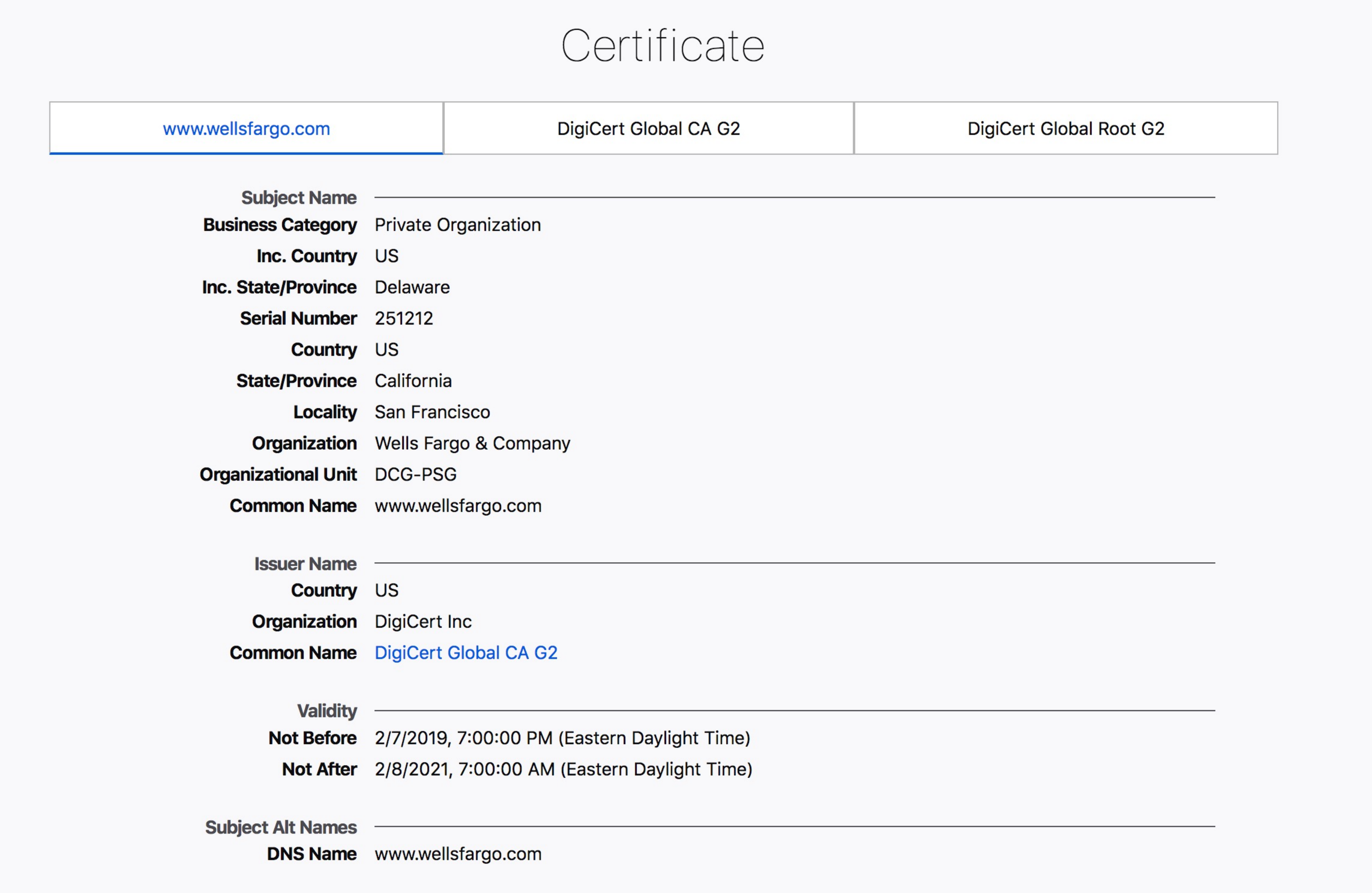
Connection secure

Certificate issued to: Wells Fargo & Company

Permissions

You have not granted this site any special permissions.

Clear Cookies and Site Data...



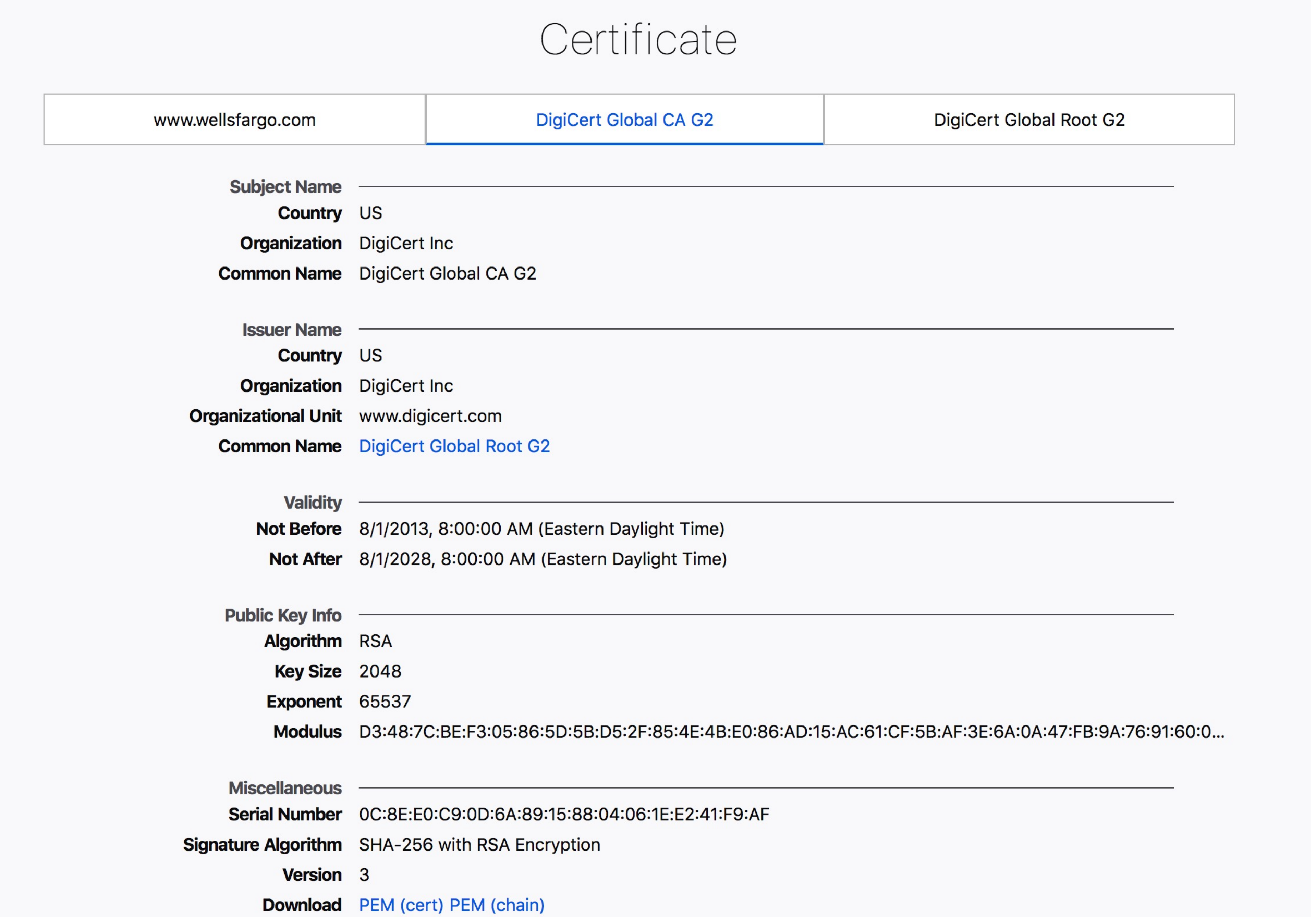
# Certificate

| Subject Name | |
|---|---|
| Business Category | Private Organization |
| Inc. Country | US |
| Inc. State/Province | Delaware |
| Serial Number | 251212 |
| Country | US |
| State/Province | California |
| Locality | San Francisco |
| Organization | Wells Fargo & Company |
| Organizational Unit | DCG-PSG |
| Common Name | www.wellsfargo.com |

| Issuer Name | |
|---|---|
| Country | US |
| Organization | DigiCert Inc |
| Common Name | DigiCert Global CA G2 |

| Validity | |
|---|---|
| Not Before | 2/7/2019, 7:00:00 PM (Eastern Daylight Time) |
| Not After | 2/8/2021, 7:00:00 AM (Eastern Daylight Time) |

| Subject Alt Names | |
|---|---|
| DNS Name | www.wellsfargo.com |



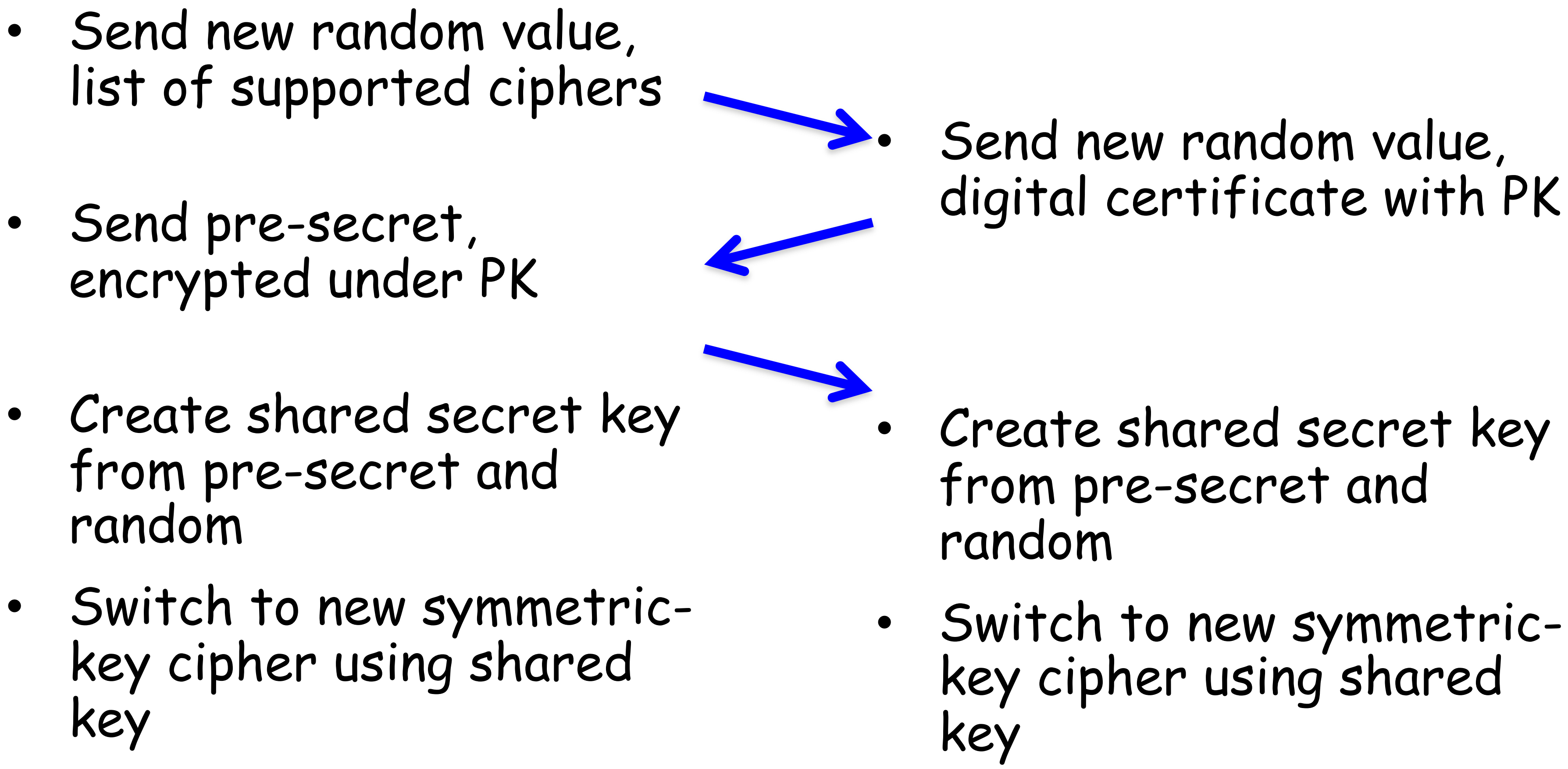
# Certificate

| | |
|---|---|
| **Subject Name** | |
| **Country** | US |
| **Organization** | DigiCert Inc |
| **Common Name** | DigiCert Global CA G2 |
| **Issuer Name** | |
| **Country** | US |
| **Organization** | DigiCert Inc |
| **Organizational Unit** | www.digicert.com |
| **Common Name** | DigiCert Global Root G2 |
| **Validity** | |
| **Not Before** | 8/1/2013, 8:00:00 AM (Eastern Daylight Time) |
| **Not After** | 8/1/2028, 8:00:00 AM (Eastern Daylight Time) |
| **Public Key Info** | |
| **Algorithm** | RSA |
| **Key Size** | 2048 |
| **Exponent** | 65537 |
| **Modulus** | D3:48:7C:BE:F3:05:86:5D:5B:D5:2F:85:4E:4B:E0:86:AD:15:AC:61:CF:5B:AF:3E:6A:0A:47:FB:9A:76:91:60:0... |
| **Miscellaneous** | |
| **Serial Number** | 0C:8E:E0:C9:0D:6A:89:15:88:04:06:1E:E2:41:F9:AF |
| **Signature Algorithm** | SHA-256 with RSA Encryption |
| **Version** | 3 |
| **Download** | PEM (cert) PEM (chain) |

# Transport Layer Security (TLS)

Based on the earlier Secure Socket Layer (SSL) originally developed by Netscape

# TLS Handshake Protocol



- Send new random value, list of supported ciphers
- Send pre-secret, encrypted under PK
- Create shared secret key from pre-secret and random
- Switch to new symmetric-key cipher using shared key

- Send new random value, digital certificate with PK
- Create shared secret key from pre-secret and random
- Switch to new symmetric-key cipher using shared key

# TLS Record Protocol

- Messages from application layer are:
  - Fragmented or coalesced into blocks
  - Optionally compressed
  - Integrity-protected using an HMAC
  - Encrypted using symmetric-key cipher
  - Passed to the transport layer (usually TCP)
- Sequence #s on record-protocol messages
  - Prevents replays and reorderings of messages

# Comments on HTTPS

- HTTPS authenticates server, not content
  - If CDN (Akamai) serves content over HTTPS, customer must trust Akamai not to change content
- Symmetric-key crypto after public-key ops
  - Handshake protocol using public key crypto
  - Symmetric-key crypto much faster (100-1000x)
- HTTPS on top of TCP, so reliable byte stream
  - Can leverage fact that transmission is reliable to ensure: each data segment received exactly once
  - Adversary can't successfully drop or replay packets

# IP Security

# IP Security

- There are range of app-specific security mechanisms
  - eg. TLS/HTTPS, S/MIME, PGP, Kerberos, …
- But security concerns that cut across protocol layers
- Implement by the network for all applications?

Enter IPSec!

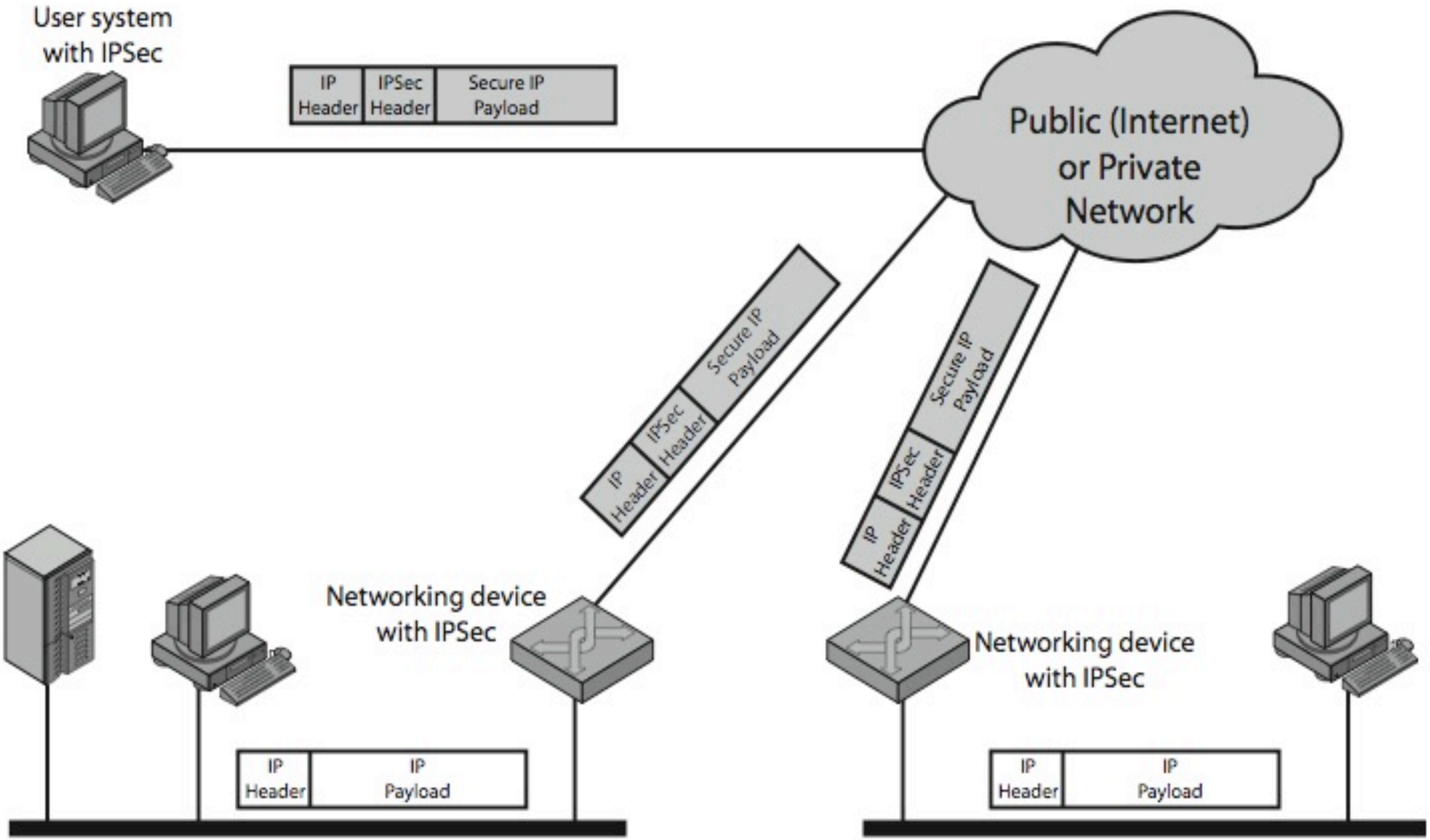
# IPSec

- General IP Security framework

- Allows one to provide
  - Access control, integrity, authentication, originality, and confidentiality

- Applicable to different settings
  - Narrow streams: Specific TCP connections
  - Wide streams: All packets between two gateways

# IPSec Uses


User system with IPSec
IP Header
IPSec Header
Secure IP Payload
Public (Internet) or Private Network
IP Header
IPSec Header
Secure IP Payload
IP Header
IPSec Header
Secure IP Payload
Networking device with IPSec
Networking device with IPSec
IP Header
IP Payload
IP Header
IP Payload

# Benefits of IPSec

- If in a firewall/router:
  - Strong security to all traffic crossing perimeter
  - Resistant to bypass
- Below transport layer
  - Transparent to applications
  - Can be transparent to end users
- Can provide security for individual users

# Conclusions

- Security at many layers
  - Application, transport, and network layers
  - Customized to the properties and requirements
- Exchanging keys
  - Public key certificates
  - Certificate authorities vs. Web of trust
- Next time
  - Network security: DNS, BGP