# 1 Introduction

## 1.1 Protocol performances

$G$: Total load, $S$ arrival rate of new packets.

### 1.1.1 Pure ALOHA

If you have data to send, send the data. If the message collides with another transmission, try resending later. On collision, sender waits random time before trying again.

$P(k \text{ transm. in } 2Xs) = \frac{(2G)^k}{k!}e^{-2G}$

$S = G \cdot P(0) = Ge^{-2G}$

### 1.1.2 Slotted ALOHA

Probability of $k$ packets generated during a slot: $P(k) = \frac{G^k e^{-G}}{k!}$ Throughput: $P(1) = Ge^{-G}$

### 1.1.3 CSMA

Goal: reduce the wastage of bandwidth due to packet collisions. Principle: sensing the channel before transmitting (never transmit when the channel is busy).

**Non-persistent** If channel is busy, directly run back off algorithm.

**p-persistent** If it is busy, they persist with sensing until the channel becomes idle. If it is idle:
- With probability $p$, the station transmits its packet
- With probability $1-p$, the station waits for a random time and senses again

**Performance of Unslotted nonpersistent CSMA** : For $a = t_{\text{prop}}/X$, the normalized one-way propagation delay. $S = \frac{G^{-aG}}{G(1+2a)+e^{-aG}}$

**Performance of Slotted nonpersistent CSMA** : $S = \frac{aG^{-aG}}{1-e^{-aG}+a}$

| Approach | SDMA | TDMA | FDMA | CDMA |
|---|---|---|---|---|
| Idea | segment space into cells/sectors | segment sending time into disjoint time-slots, demand driven or fixed patterns | segment the frequency band into disjoint sub-bands | spread the spectrum using orthogonal codes |
| Terminals | only one terminal can be active in one cell/one sector | all terminals are active for short periods of time on the same frequency | every terminal has its own frequency, uninterrupted | all terminals can be active at the same place at the same moment, uninterrupted |
| Signal separation | cell structure, directed antennas | synchronization in the time domain | filtering in the frequency domain | code plus special receivers |
| Advantages | very simple, increases capacity per km² | established, fully digital, flexible | simple, established, robust | flexible, less frequency planning needed, soft handover |
| Dis-advantages | inflexible, antennas typically fixed | guard space needed (multipath propagation), synchronization difficult | inflexible, frequencies are a scarce resource | complex receivers, needs more complicated power control for senders |
| Comment | used in all cellular systems | standard in fixed networks, together with FDMA/SDMA used in many mobile networks | typically combined with TDMA (frequency hopping patterns) and SDMA (frequency reuse) | higher complexity |

## 1.2 Exercises

Capacity of a link vs Transmission capacity (=total capacity of all the links). Wire : $C_t = \min\{C_1, C_2\}$ Wireless : $d/C_t = d/C_1 + d/C_2 \leftrightarrow C_t = (c_1c_2/c_1 + c_2)$

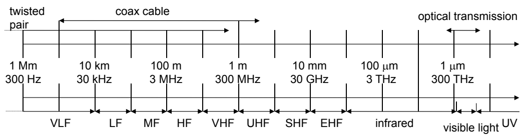
ALOHA : Aloha channel with infinite number of users gives 94% of idle slots. $P(0) = e^{-G} = 0.94 \to G = 0.062$

$S = P(1) = Ge^{-G} \approx 5.8\%$

$G < G_{peak} = 1$ : channel underloaded.

Ration of busy slots occupied by collisions : $\frac{1-P(0)-P(1)}{1-P(0)} = 3.3\%$

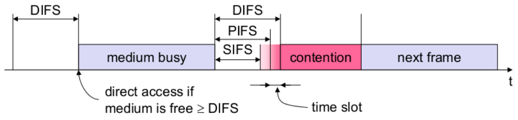
# 2 WLAN Engineering aspects



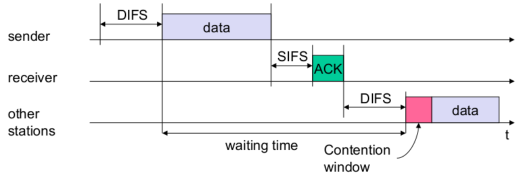

Frequency(f) and wave length($\lambda$), $c = 3 \times 10^8 m/s$ : $\lambda = c/f$

## 2.1 802.11

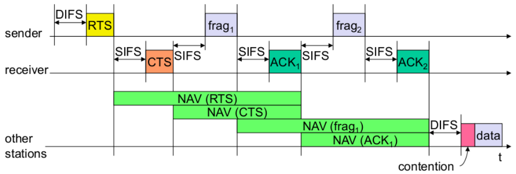
**Physical layer** : DSSS or FHSS, **MAC Layer** : best effort asynchronous data service, DCF CSMA/CA (mandatory), DCF with RTS/CTS or PCF (optional)




CSMA/CA Unicast :




DCF with RTS/CTS (with fragmentation) :




MAC address format :

| scenario | to DS | from DS | address 1 | address 2 | address 3 | address 4 |
|---|---|---|---|---|---|---|
| ad-hoc network | 0 | 0 | DA | SA | BSSID | - |
| infrastructure network, from AP | 0 | 1 | DA | BSSID | SA | - |
| infrastructure network, to AP | 1 | 0 | BSSID | SA | DA | - |
| infrastructure network, within DS | 1 | 1 | RA | TA | DA | SA |

## 2.2 Exercises

Wireless LAN use polling between M workstations and a central access point. Channel at 25Mbps. Stations 100 m away from AP, polling messages 64 bytes long. Packet length : 1250 bytes. No more packet indicated with 64-byte message. Maximum arrival rate $\lambda_{max} = \rho_{max} * Br/P_{length}$ $\rho_{max} = \frac{Effectivetime}{Wholetime} = \frac{M*N*T_{packet}}{M*(NT_{packet}+T_{poll}+T_{end}+2t_{prop})}$

$t_{prop} = d/c$ $T_{packet} = \frac{1250*8}{25*10^6}$

One station A sends a frame to another station B in a different BSS in an IEEE 802.11 infrastructure network with DCF access method without RTS/CTS.

A → AP1

| To | From | Type | Dur | A1 | A2 | A3 |
|---|---|---|---|---|---|---|
| 1 | 0 | Data | $T_d + SIFS + T_A$ | BSS1 | A | B |

AP1 → A

| To DS | From DS | Type | Duration | Addr. 1 |
|---|---|---|---|---|
| 0 | 0 | ACK | 0 | A |

AP1 → AP1

| To | From | Type | Dur | A1 | A2 | A3 |
|---|---|---|---|---|---|---|
| 1 | 1 | Data | $T_d + S + T_A$ | AP1 | B | A |

AP2 → AP1

| To DS | From DS | Type | Duration | Addr. 1 |
|---|---|---|---|---|
| 0 | 0 | ACK | 0 | AP1 |

AP2 → B

| To | From | Type | Dur | A1 | A2 | A3 |
|---|---|---|---|---|---|---|
| 0 | 1 | Data | $T_d + S + T_A$ | B | BSS2 | A |

B → AP2

| To DS | From DS | Type | Duration | Addr. 1 |
|---|---|---|---|---|
| 0 | 0 | ACK | 0 | BSS2 |

# 3 Bianchi model

$\pi$, probability of transmission, $p$, probability of collision, $b_{i,k}$ stationary probability of state $i, k$: $p = 1 - (1-\pi)^{N-1}$

$\pi = \sum_{i=0}^{m} b_{i,0} = \frac{b_{0,0}}{1-p} = \frac{2(1-2p)}{(1-2p)(W_{min}+1)+pW_{min}(1-(2p)^m)}$

$= \frac{2}{1+W_{\min}+pW_{\min}\sum_{k=0}^{m-1}(2p)^k}$

$$b_{i,k} = \frac{CW_i - k}{CW_i} \cdot \begin{cases} (1-p)\sum_{j=0}^{m} b_{j,0} & i = 0 \\ p \cdot b_{i-1,0} & 0 < i < m \\ p \cdot (b_{m-1,0} + b_{m,0}) & i = m \end{cases}$$

## 3.1 Saturation throughput

$$\tau = \frac{E[\text{Payload Transmitted by user i in a slot time}]}{E[\text{Duration of slot time}]}$$

$$= \frac{P_s P_{tr} L}{P_s P_{tr} T_s + P_{tr}(1-P_s)T_c + (1-P_{tr})T_{id}},$$

$$P_s = \frac{N\pi(1-\pi)^{N-1}}{1-(1-\pi)^N},$$

$$P_{tr} = 1-(1-\pi)^N,$$

$$T_s = t_{\text{header}} + t_{\text{payload}} + \text{SIFS} + t_{\text{ACK}} + \text{DIFS} + 2\sigma,$$

$$T_c = t_{\text{header}} + t_{\text{payload}} + \text{SIFS} + \sigma$$

## 3.2 DOMINO Cheating detection

| Cheating Method | Detection Test |
|---|---|
| Frame scrambling | Number of retransmissions |
| Oversized NAV1 | Comparison of the declared and actual NAV values |
| Transmission before DIFS | Comparison of the idle time after the last ACK with DIFS |
| Backoff manipulation | Actual Backoff/ Consecutive Backoff |
| Frame scrambling with MAC forging | Periodic dummy frame injection |

# 4 Trunk dimensioning

For a trunk of $N$ channels, an offered load $A = \lambda E[X]$, $X$ the call duration, $Y$ the call arrival per sec $\sim$ Poisson($\lambda$) and $\rho$ the traffic carried by each channel:

$$P_{\text{Blocking}} = P(\text{Drop a call because busy line})$$

$$= \frac{A^N}{N!\sum_{i=0}^{N}(\frac{A^i}{i!})}$$

$$\rho = \frac{(1-P_{\text{blocking}})A}{N}$$

**Cellular efficiency** $E = \frac{Conversations}{cells \times MHz}$

# 5 Cellular Geometry: Hexagons

**Area**: $A = 1.5R^2\sqrt{3}$

**Distance btw. adjacent cells**: $d = \sqrt{3}R$

## 5.1 Co-channel interference

**Co-channel reuse ratio** : $Q = \frac{D}{R} = \sqrt{3N}$ with $D$ the **distance** to the nearest co-channel cell, $R$ the **radius** of a cell and $N$ the **cluster size**.

**Signal to Interference ratio (SIR)** : $\text{SIR} = \frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i}$. With $S$ the desired signal **power**, $I_i$ the **interference power** from the $i$th interfering co-channel base-station, $i_0$ the **number of co-channel** interfering cells.

**Signal to Interference plus Noise ratio (SINR)** : $\text{SINR} = \frac{S}{I+N_0}$

**Average received power** $P_r$ : $P_r = P_0(\frac{d}{d_0})^{-\alpha}$ or $P_r(\text{dBm}) = P_0(\text{dBm}) - 10\alpha\log(\frac{d}{d_0})$ with $P_0$ the power received from a small distance $d_0$ from the transmitter and $\alpha$ the path loss exponent.

**SIR in the corner of a cell** : $\frac{S}{I} = \frac{R^{-\alpha}}{\sum_{i=1}^{i_0} D_i^{-\alpha}}$

**First interfering layer approximation** : $\frac{S}{I} = \frac{(\frac{D}{R})^\alpha}{i_0} = \frac{(\sqrt{3N})^\alpha}{i_0}$ eg. $= (\frac{D}{R})^2\frac{1}{2}$ for two first layer interferers (cell divided into 3 sectors with directional antennas.)

## 5.2 Capacity of a cellular network

For $B_t$ the total allocated spectrum and $B_c$ the channel bandwidth:

$$m = \frac{B_t}{B_c\frac{Q^2}{3}} = \frac{B_t}{B_c\left(\frac{6}{3^{\frac{\alpha}{2}}}\left(\frac{S}{I}\right)_{\min}\right)^{\frac{2}{\alpha}}} = \lfloor\frac{C}{N}\rfloor$$

For a cluster size $N$, $N = (i+j)^2 - ij$ for $i, j = 0, 1, 2, \ldots$ and number of channels $C$.

### 5.2.1 CDMA Capacity: single cell case

For the bitrate $R$, available bandwidth $W$, noise spectral density $N_0$, thermal noise $\eta$, received user signal (at base station) $S$, we have a possible number $N$ of users:

$$N = 1 + \frac{W/R}{E_b/N_0} - (\frac{\eta}{S})$$

With a duty cycle $\delta$ (Discontinuous transmission mode: takes advantage of intermittent nature of speech):

$$N = 1 + \frac{1}{\delta}\frac{W/R}{E_b/N_0} - (\frac{\eta}{S})$$

And if we have $m$ sectors, the effective capacity becomes $mN$.

### 5.2.2 CDMA multiple cells

**Frequency reuse factor on the uplink** $f = \frac{N_0}{N_0+\sum_i U_i N_{ai}}$ where $N_0$ = total interference power received from $N-1$ in-cell users, $U_i$ = number of users in the$i^{\text{th}}$ adjacent cell and $N_{ai}$ = average interference power from a user located in the $i^{\text{th}}$ adjacent cell

**Average received power from users in adjacent cell** $N_{ai} = \sum_j N_{ij}/U_i$ where $N_{ij}$ = power received at the base station of interest from the $j^{\text{th}}$ user in the $i^{\text{th}}$ cell

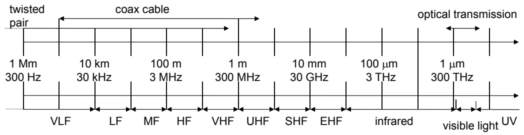
# 6 Noise

**Categories** : Thermal Noise, Intermodulation Noise, Cross-talk, Impulse Noise.

**Thermal Noise** $N_0 = kT$ $(W/Hz)$

For signal power $S$, bitrate $R$, $k = 1.3806 \cdot 10^{-23} JK^{-1}$ the Boltzmann constant and $T$ the temperature: $\frac{E_b}{N_0} = \frac{S/R}{N_0} = \frac{S}{kTR}$

## 7 Wireless Misc Stuff




**Mobile IP Requirements** : Transparency, Compatibility, Security, Efficiency, Scalability.

**Mobile IP Issues** : Security(Authentication to FA is problematic), Firewalls, QoS

**Network Layers** Top-down: Application, Transport, (HIP layer), Network, Data-link, Physical.

### 7.1 Ad-hoc Netowrks

**Upper Bound for the Throughput** If we have $n$ identical randomly located nodes each capable of transmitting $W$ bits/s. Then the throughput $\lambda(n)$ obtainable by each node for a randomly chosen destination is $\lambda(n) = \Theta\left(\frac{W}{\sqrt{n \log n}}\right)$

**Routing** *proactive*: DSDV, OLSR. *reactive*: AODV, DSR

### 7.2 Antennas & Propagation

Free space propagation, received power: $P_{\mathrm{R}} = P_{\mathrm{T}} \frac{A_{\mathrm{R}}}{4\pi d^2} \eta_{\mathrm{R}}$ with $\eta_{\mathrm{R}}$ an efficiency parameter, $A_{\mathrm{R}}$ the receiving antenna area.
Focusing capability, depends on size in wavelength $\lambda$: $G_{\mathrm{T}} = 4\pi\eta_{\mathrm{T}} A_{\mathrm{T}}/\lambda^2$
Directional emitter, received power: $P_{\mathrm{R}} = P_{\mathrm{T}} G_{\mathrm{T}} \frac{A_{\mathrm{R}}}{4\pi d^2} \eta_{\mathrm{R}}$
Free space received power: $P_{\mathrm{R}} = P_{\mathrm{T}} G_{\mathrm{T}} G_{\mathrm{R}} (\frac{\lambda}{4\pi d})^2$
Loss: $L = \frac{P_T}{P_R} = \frac{(4\pi d)^2}{G_R G_T \lambda^2}$
$c = 3 \cdot 10^8$
Parabola: $G = \frac{7A}{\lambda^2}$

**Mobnet Decibels** : $B = 10 \log(\frac{P}{P_0})$

**Propagation modes** *Ground Wave*: $f \leq 2$ Mhz, *Sky Wave*, *Line of Sight*: $f \geq 30$ Mhz

#### 7.2.1 Line of sight equations

Horizon distance $d$[km] in **kilometers**, antenna height $h$[m] and refraction adjustment factor $K = 4/3$:

**Optical LOS** : $d = 3.57\sqrt{h}$

**Effective LOS** : $d = 3.57\sqrt{Kh}$

**Max LOS distance for two antennas :**

$$3.57(\sqrt{Kh_1} + \sqrt{Kh_2})$$

### 7.3 Free Space Loss

Free space loss, ideal isotropic antenna:

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

Free space loss equation can be recast:

$$L_{DB} = 10 \log \frac{P_t}{P_r} = 20 \log(f) + 20 \log(d) - 147.56dB$$

Free space loss accounting for gain of other antennas:

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_r G_t \lambda^2} = \frac{(cd)^2}{f^2 A_r A_t}$$

$G_t$ = gain of transmitting antenna
$A_r$ = effective area of receiving antenna

### 7.4 Forward Error Correction (FEC)

Redundancy in packets to allow limited error correction at the receiver: used in 802.11a (Convolutional), HSDPA (Turbo Codes) and 802.11n (LDPC).

## 8 TCP

### 8.1 Standard

**Tahoe** Basic TCP. Three duplicate ACK's provoke fast retransmit (resend 1st missing packet), set `ssthresh` to `cwnd/2`, `cwnd` to 1 and provoke slow start.

**Reno** Three duplicate ACK's provoke fast retransmit, `ssthresh` to `cwnd/2`, `cwnd` to `ssthresh + 3` and enter fast recovery.

**Fast Recovery** Increase `cwnd` by 1 segment for every received duplicate ACK. (Warning, unlogical: When new ACK is received, `cwnd = ssthresh` and enter congestion avoidance). If a timeout occurs, set `cwnd` to 1 and enter slow start.

**New Reno Fast Recovery** More intelligent fast recovery where you remember the last received ACK.

### 8.2 Mobile

**Indirect TCP (I-TCP)** Connection split at FA. Standard TCP on the wire line, wireless optimized TCP on the wifi side: shorter timeout, faster retransmission. Loss of end-to-end semantics, security issues.

**Mobile TCP (M-TCP)** Split connection at FA. Monitor packets, if a disconnect is detected, report receiver window = 0: sender will go into persist mode and doesn't timeout or modify his congestion window. Preserves end-to-end semantics. Disadv.: wifi losses propagate to the wire network, link-errors pkt loss must be resent by sender, security issues. Summary: only handles mobility errors, no transmission errors.

**Snooping-TCP** TCP-aware link layer: Split connections, FA buffers and retransmits segments, does not ACK buffered packets (preserves end-to-end semantics).

**Transaction oriented TCP (T-TCP)** TCP phases: connection setup, data transmission, connection release. T-TCP combines these steps and only 2-3 packets are needed for short messages. Efficient for single packet transactions, but requires TCP modifications on all hosts.

## 9 Security

**Security Requirements** : Confidentiality, Authenticity, Replay Detection, Integrity, Access Control, Jamming Protection.

**GSM** Shared secret and challenge responses, one-way authentication.

**3GPP** (Improvements from GSM) Two-way authentication, avoid fake base station, cipher keys and auth data is now encrypted, integrity. Privacy/Anonymity not completely protected however.

## 10 Privacy

**Privacy Related Notions** Anonymity, untraceability, unlinkability, unobservability, pseudonymity

**Best to worst against information leakage:** GPS: no third-party, determined 'alone'. Cell-ID: requires the operator database that is relatively protected (they won't easily mine you). Wireless: requires one or several third-party owned databases that can track you, and it is relatively precise due to short radio range.

### 10.1 Privacy Metrics

**Entropy-Based Anonymity** $A$ the anonymity set, $p_x$ the probability for an external observer that the action was performed by $x$:

$$\sum_{\forall x \in A} p_x \log(p_x)$$

**Entropy-Based Unlinkability** $I_1, I_2$, sets of elements to be related, $p_r$, the probability two elements are related for an external observator:

$$\sum_{\forall R \subseteq I_1 \times I_2} p_r \log(p_r)$$

### 10.2 RFID

**Standard tags possibilities** : Kill, Sleep, Rename, Block, (Legislation).

**Crypto enabled tags possibilities** : Tree-approach, synchronization approach, hash chain based approach.

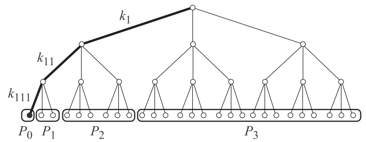
**Singulation** (determining which tags are present around the reader) Binary tree walking: reader first asks the tags to emit the first bit of their ID. If every answer is 0 (or 1) the reader knows on which side the ID's are. This is done recursively until all ID's are determined. A **collision** is the event where ID's on both sides of a node answer and both sides must be recursed upon.

**Privacy zone** A tag ID can be changed so that it lies in the *private* zone of the tree. A special device simulates collisions for every query in this area, so an exhaustive search would be required to find a tag.

**Pseudonyms** Tags can be set to use different ID's that an authorized reader would know how to correlate. To avoid having too complex tags, the reader will generally be responsible for *refilling* the pseudonyms. This will be done in cleartext and assumes an attacker does not always listen.

#### 10.2.1 Key Tree

Tags are the leaves of a tree with branching factor $b$ and depth $d$, and each edge to arrive to a tag has an associated key: hence, a tag has $d$ associated keys. Maximize branching factor at the first level for strong anonymity.




**Anonymity set** has minimum size of 1, maximum size of all the tags. Compromising a tag yields all the keys leading to it and permit to partition the other tags (neighbors in the tree share common keys) : $P_0$ contains the compromised tag, $P_1$ contains the compromised tag's *brothers* not being in $P_0$, etc. Tags that belong to larger partitions have better privacy (e.g: tags in $P_3$ are not distinguishable, attacker only knows they don't use $k_1$.)

**Expected size of the anonymity set for a random tag** : for $n$ the total number of tags and $|P_i|/n$ the probability of selecting a tag from partition $P_i$

$$\bar{S} = \sum_{i=0}^{d} \frac{|P_i|}{n} |P_i| = \sum_{i=0}^{d} \frac{|P_i|^2}{n}$$

**Normalized expected anonymity** : Using $n = b^d$ and $|P_0| = 1, |P_1| = b - 1, |P_2| = (b-1)b, \ldots, |P_l| = (b-1)b^{l-1}$.

$$R = \frac{\bar{S}}{n} = \sum_{i=0}^{d} \frac{|P_i|^2}{n^2} = \frac{b-1}{b+1} + \frac{2}{(b+1)n^2}$$

For **one** tag in $P_i$, the linkability probability is $1/|P_i| \rightarrow$ global linkability in $P_i$ is $|P_i| \frac{1}{|P_i|} = 1$. For $l$ partitions, the probability that two transactions from a randomly chosen tag are linkable is (with $n = b^d$):

$$\frac{1}{n} \sum_{i=1}^{l} (|P_i| \frac{1}{|P_i|}) = \frac{l}{n}$$

## 11 Comparisons

This amazing cheat-sheet was brought to you by *Julien Perrochet*, *Christopher Chiche* and *Tobias Schlatter*. Follow us on GitHub: `https://github.com/Shastick/mobnet2012` !

Values of $N$: 0,1,3,4,7,9,12,13,16,19,21,25,27,28,31,36,37,39,43,48,49,52,57,61,63,64,67,73,75,76,79,81,84,91,93,97,100,103,108,109,111,112,117,124,127,129,133,139,147,148,151,156,169,171,175,192,193,196,217,219,243,244,271,300

**ACO** Authenticated Cipher Offset
**AIFS** Arbitrary Inter-Frame Space
**AMF** Authentication and Key management Field
**AODV** Ad Hoc On-demand Distance-Vector
**AP** Access Point
**AP** Access Point
**ATIM** Ad-hoc Traffic Indication Map
**AUTN** Authentication Token
**AV** Authentication Vector
**BO** BackOff
**BSSID** Basic Service Set Identifier
**BSS** Basic Service Set
**CARMA** Collision Avoidance and Resolution Multiple Access
**CA** Collision Avoidance
**CCA** Clear Channel Assessment
**CDMA** Code Division Multiple Access
**CH** Correspondant Host
**CN** Correspondant Node
**COA** Care-Of Address
**CRC** packet received CoRreCtly
**CSMA/CD** CSMA with Collision Detection
**CSMA** Carrier Sense Multiple Access
**CTS** Clear To Send
**CW** Contention Window
**DAMA** Demand-Assigned Multiple Access
**DA** Destination Address
**DBPSK** Differential Binary Phase Shift Keying
**DCF** Distributed Coordination Function
**DECT** Digital Enhanced Cordless Telecommunications
**DHCP** Dynamic Host Configuration Protocol
**DH** Diffie-Hellman
**DNS** Domain Name System
**DQPSK** Differential Quadrature Phase Shift Keying
**DSDV** Destination Sequenced Distance Vector
**DSRC** Dedicated Short Range Communications
**DSR** Dynamic Source Routing
**DSSS** Direct Sequence Spread Spectrum
**DS** Differentiated Service
**DS** Distribution System
**DTIM** Delivery Traffic Indication Map
**DoS** Denial of Service
**EAP-TLS** TLS over EAP
**EAPOL** EAP Over LAN
**EAP** Extensible Authentication Protocol
**EDCA** Enhanced Distributed Channel Access
**EHF** Extra High Frequency
**EPC** Electronic Product Code
**ESP** Encapsulating Security Payload
**ESS** Extended Service Set
**FAMA** Floor Acquisition Multiple Access
**FA** Foreign Agent
**FDD** Frequency Division Duplex
**FDMA** Frequency Division Multiple Access
**FEC** Forward Error Correction
**FHSS** Frequency Hopping Spread Spectrum
**FQDN** Fully Qualified Domain Name
**GFSK** Gaussian Frequency Shift Keying
**GMK** Group Master Key
**GPRS** General Packet Radio Service
**GSM** Global System for Mobile Communication
**HA** Home Agent
**HCCA** HCF Controlled Channel Access
**HCF** Hybrid Coordination Function
**HF** High Frequency
**HIP** Host Identity Protocol
**HIT** Host Identity Tag
**HI** Host Identifier
**HMIP** Hierarchical Mobile IP
**HSPDA** High Speed Downlink Packet Access
**ICMP** Internet Control Message Protocol
**IFS** Inter Frame Spacing
**IHL** Internet Header Length
**IKE** Internet Key Exchange
**IMSI** International Mobile Subscriber Identity
**ISI** InterSymbol Interference
**KISS** Keep It Simple and Stupid
**LDPC** Low Density Parity Check
**LEAP** Light EAP
**LFSR** Linear Feedback Shift Register
**LF** Low Frequency
**LTE** Long Term Evolution
**MACA-BI** MACA By Invitation
**MACA** Multiple Access with Collision Avoidance (RTS-CTS(+ACK))
**MAC** Message Authentication Code
**MAHO** Mobile Assisted Handover
**MAP** Mobility Anchor Point
**MD** Mobile Device
**MF** Medium Frequency
**MH** Mobile Host
**MIB** Management Information Base
**MIC** Message Integrity Code
**MN** Mobile Node
**MSC** Mobile service Switching Center
**MTSO** Mobile Telecommunications Switching Office
**NAASS** Normalized Average Anonymity Set Size
**NAT** Network Address Translation
**NAV** Net Allocation Vector
**OFDMA** Orthogonal Frequency-Division Multiple Access
**OLSR** Optimized Link- State Routing
**OTP** One-Time Password
**PCF** Point Coordination Function
**PEAP** Protected EAP
**PEP** Performances Enhancing Proxies
**PIN** Personal Identification Number
**PLCP** Physical Layer Convergence Protocol
**PMD** Physical Medium Dependent
**PMK** Pairwise Master Key
**PN** Pseudo-random Noise
**PSTN** Public Switched Telephone Network
**PTK** Pairwise Transient Key
**QoS** Quality of Service
**RADIUS** Remote Authentication Dial-In User Service
**RA** Receiver Address
**RERR** Route ERRor
**RFID** Radio Frequency Identification
**RREP** Route REPly
**RREQ** Route REQuests

**RSN** Robust Security Network
**RTCP** Real Time Control Protocol
**RTM** Retransmission TimeOut
**RTP** Real Time Protocol
**RTS** Request To Send
**RVS** Rendez-Vous Server
**RWND** Receiver Window
**SACK** Selective ACKnowledgment
**SA** Security Association
**SA** Source Address
**SDMA** Space Division Multiple Access
**SHF** Super High Frequency
**SIFS** Short Inter Frame Spacing
**SIM** Subscriber Identity Module
**SIP** Session Initiation Protocol
**SPI** Security Parameter Index
**SSTresh** Slow Start Threshold
**STA** STAtion
**STA** Station
**TA** Transmitter Address
**TCP** Transmission Control Protocol
**TDD** Time Division Duplex
**TDMA** Time Division Multiple Access
**TIM** Traffic Indication Map
**TKIP** Temporal Key Integrity Protocol
**TLS** Transport Layer Security
**TMSI** Temorary Mobile Subscriber Identity
**TOS** Type Of Service
**TSF** Timing Synchronisation Function
**TTL** Time To Live
**UHF** Ultra High Frequency
**UMTS** Universal Mobile Telecommunications System
**UV** Ultraviolet Light
**VANET** Vehicular Ad-hoc NETwork
**VHF** Very High Frequency
**VLF** Very Low Frequency
**WAP** Wireless Access Point
**WEP** Wired Equivalent Privacy
**WLAN** Wireless Local Area Network
**WMN** Wireless Mesh Network
**WPAN** Wireless Personal Area Network
**WPA** WiFi Protected Access