Appendix A
Backward Algorithm

Recall from Fig. 5.8 in Chap. 5 that forward algorithm was used to estimate the *SP* and *EP* for the observation sequence $O = O_1, O_2, \ldots, O_v$.

The backward algorithm is concerned with estimating the future observation sequence from a given state. The backward algorithm computes $P(O_{v+1:t}|X_v)$, such that the overall observation sequence is $O_{k=t} = O_1, O_2, \ldots, O_v, \ldots, O_{t-1}, O_t$.

Therefore, the backward variables are expressed as:

$$\beta_n(j) = P(O_{v+1}, \ldots, O_t | X_v = j) \tag{A.1}$$

Collectively, the forward and backward variables are used to compute the so-called posterior probability (Xu and Gogarten 2008):

$$\gamma_n(i) = \frac{\alpha_n(i)\beta_n(i)}{P(S)} \tag{A.2}$$

Figure A.1 shows the application of the forward and backward algorithm on an observation sequence of length $k = t$.

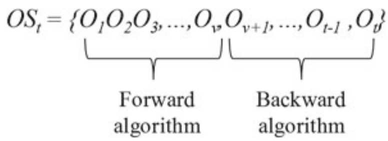

Fig. A.1 The forward and backward algorithm applied to an observation sequence

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Appendix B
EAP Authentication Mechanism

Instead of conventional security mechanisms, EAP uses port-based authentication. A port can be seen as a point of attachment to the network, which opens only when the mobile node successfully completes the authentication procedure. The port-based mechanism is a general approach which may also be used in conjunction with authentication mechanisms other than EAP. However, its combination with EAP is most commonly employed.

The EAP authentication mechanism comprises the following elements:

- Supplicant: this is the mobile node seeking WLAN services. It has to provide valid user credentials to complete authentication.
- Authentication Server: this is an external server (e.g. RADIUS) which verifies user credentials against a database before allowing access to the network.
- Authenticator: this is the WLAN AP which would serve the supplicant. Authenticator plays an intermediary role in the authentication process between the supplicant and the Authentication Server.

The procedure begins when the supplicant identifies itself with the authenticator and requests to initiate the EAP procedure. The authenticator identifies the supplicant and sends the response packet. After receiving the response and initiating the EAP, the supplicant starts the Secured Socket Layer (SSL) handshake procedure. SSL was introduced by Netscape communications for securing information exchange over the World Wide Web. In the EAP, it ensures a secured transfer of supplicant and server certificates. On top of the SSL layer, Protected EAP (PEAP) provides another security layer by encapsulating the messages between the supplicant and the server.

A successful EAP session generates Pairwise Master Key (PMK) for both the supplicant and the server. PMK is also delivered to the authenticator via a secure layer, and is used in all subsequent communications. The same PMK is used to generate another key called the Pairwise Transient Key (PTK). The difference between PMK and PTK is that PMK acts as a pass phrase for the entire user

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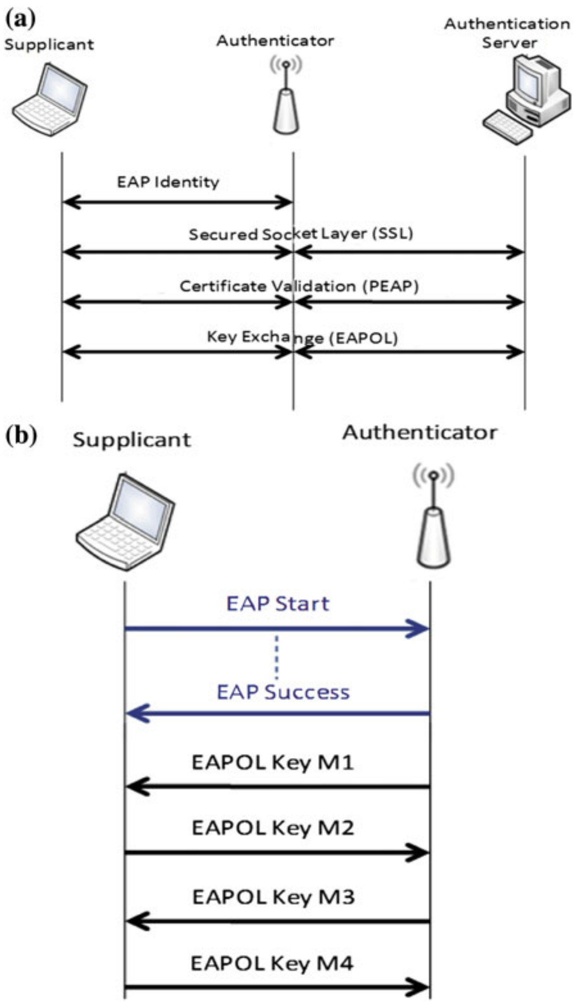

Fig. B.1 EAP authentication mechanism (Hasan et al. 2010b). **a** The four processes involved in the EAP authentication mechanism. **b** The key exchange involved in the EAPoL process of the EAP authentication mechanism

session while the PTK is used for encrypting the data exchange between the supplicant and the authenticator. To derive PTK from PMK, a 4-way handshake between the authenticator and supplicant is executed. This handshake is collectively referred to as the EAP over LAN (EAPoL) key exchange. The EAP procedure is therefore classified into four processes, EAP identity, SSL, PEAP, and EAPoL, as shown in Fig. B.1a. The key exchange involved during the EAPoL phase is shown in Fig. B.1b.

Appendix C
Software Tools

This appendix briefly introduces three tools (IPerf, Vistumbler, Network monitor) that have been extensively used in this book. These tools are independent of each other and suffice for different purposes.

IPerf

IPerf is a command line tool that measures network throughput by generating and transmitting TCP/UDP packets over the concerned network. In a typical setup, IPerf sends these packets from source node to the destination and reports the achievable throughput. It is also capable of reporting other parameters such as packet loss, delay, and jitter. IPerf can be used on both wired and wireless networks. Refer to Schroder (2008) for more information.

IPerf has been used in Sects. 3.2.2, 3.2.3 and 7.4.2 for measuring data rates in both stationary and vehicular setups.

Vistumbler

Vistumbler is Windows Vista compatible version of Netstumbler, which is commonly used in war driving tests. Vistumbler listens to the periodic beacon messages transmitted by the roadside APs and collects information on APs' signal strength, authentication scheme, encryption, radio type, population, etc. It also reports the time of receiving first and last beacon message from a particular AP. This time difference is referred to as the encounter time in this book (see Sect. 3.3.2). Vistumbler is meant for recording WLAN AP information only. It also supports GPS logs, however, positioning information has not been used in this work.

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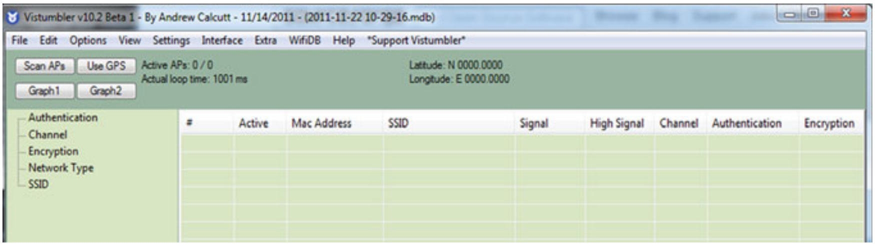

Fig. C.1 Vistumbler user interface

This book uses Vistumbler in Sect. 3.2.1 for measuring signal strengths of roadside APs. It is used in Sects. 3.3.2 and 5.5.1 for recording population, encounter durations, radio types, and authentication information of the roadside APs. Section 7.4.1 also uses vistumbler to report AP population in three different geographical areas.

Windows Network Monitor

Windows Network Monitor (WNM) provides enhanced functionalities for packet capture in wired and wireless networks. In this book, WNM has been used to capture and analyze packet exchange that occurs during handovers in 802.11 networks. In addition to the detailed information on the captured packets, WNM reports the time at which a certain packet is received. Time difference between two consecutive packets is interpreted as the time delay (or time offset in WNM environment). It also reports the signal strength with which a certain packet is captured. Refer to Tulloch et al. (2009) for more information.

WNM is used in Sect. 3.2.3 for recording signal strength operating in parallel with IPerf that measures data rates. It has been used in Sect. 7.3 for evaluating delay in different phases of handover.

Others

In addition to IPerf, Vistumbler, and WNM, Sect. 3.3.3 uses Online Eye Pro for measuring throughput while Sect. 7.4.2 uses Net Surveyor to report the number of APs operating on a particular channel.

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