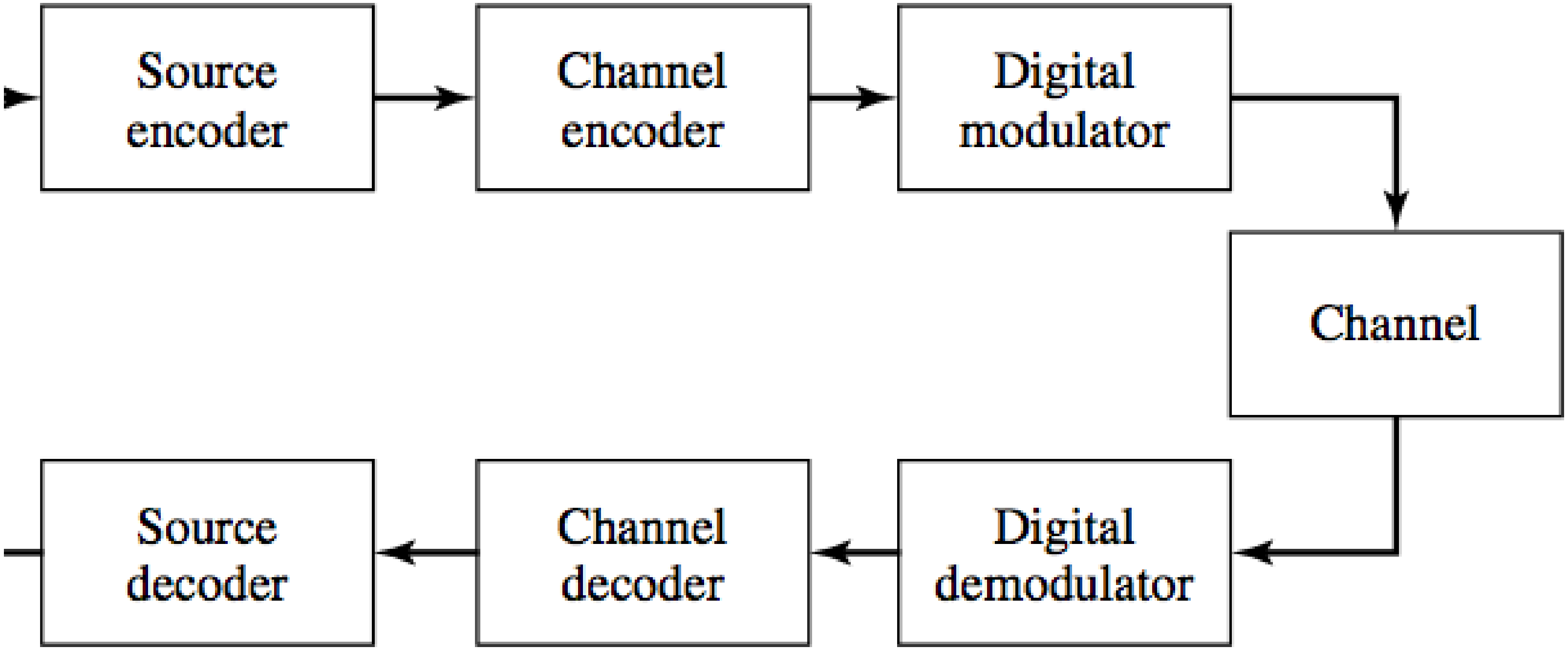
Wireless Physical Layer

Wireless Link

- Processing at the transmitter
- Propagation through the channel
- Processing at the receiver

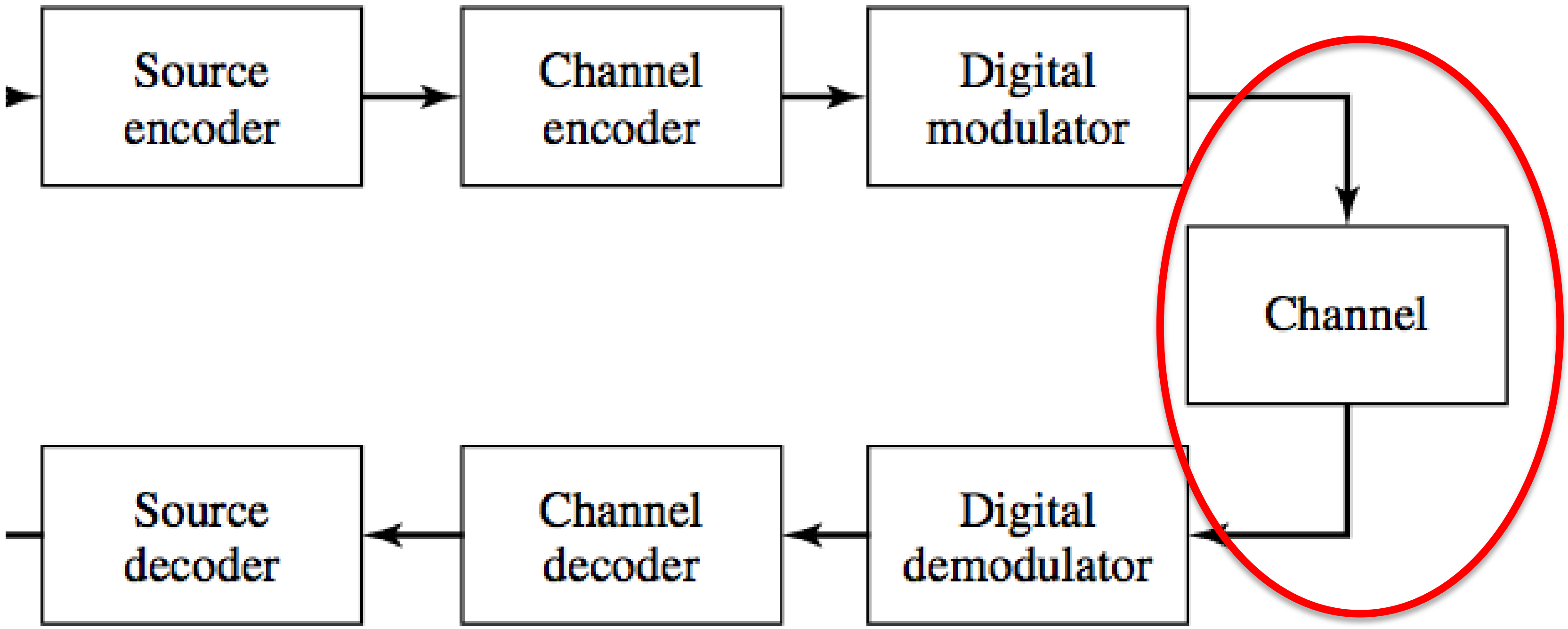
Basic Elements of a Digital Communication System



Basic Elements Contd.

- Source Encoding
  - Encode information into bits.
- Channel Encoding
  - Add enough redundancy so that some basic reliability is achieved.
- Modulation
  - Map the digital info on signal waveform
- Channel
  - Abstraction of the physical medium that carries the signal. Characterized by noise.

Modeling Wireless Channel



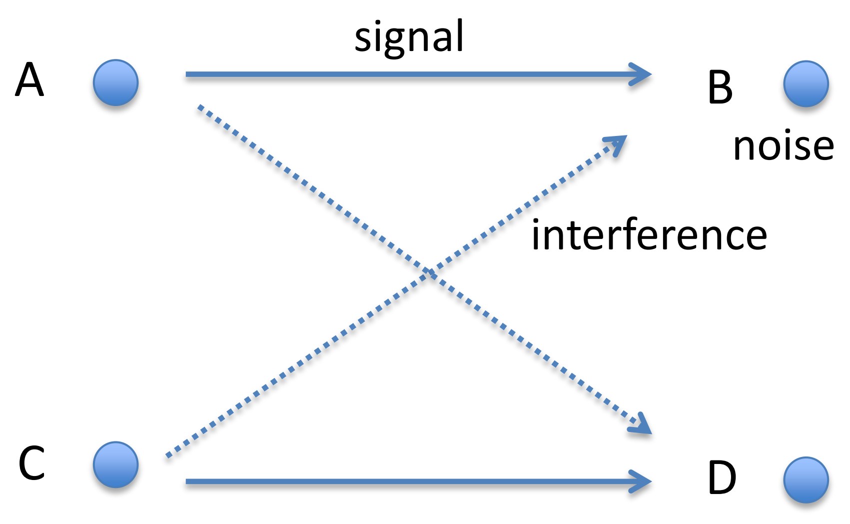
Noise in Wireless Channel

- Noise causes signal degradation via a variety of mechanisms.
  - Eventually causes bit errors.
- Various sources of noise
  - – thermal noise at the receiver, or radio signals already present in nature.
  - Noise is different from interference.

Modeling Wireless Channel

- Both Noise and Interference add to the intended signal.
- Interference is not noise. Interference is somebody else's signal.

Note that wireless channels are naturally broadcast



B receives signal
+ interference
+ noise

Concept of SINR

- *SINR* = Signal to Interference plus Noise Ratio.

$$SINR = \frac{S}{I+N}$$

S , N and I are powers as sensed at the receiver.

- The concept of SINR is important as it determines how "strong" the link is.
- This determines bit rates that can be supported and bit error rates experienced.

Bit Error Rate (BER)

- Fraction of bits received incorrectly. Also, called bit error probability P_b.
- BER depends on
  - SINR
  - Modulation technique
  - Bit rate

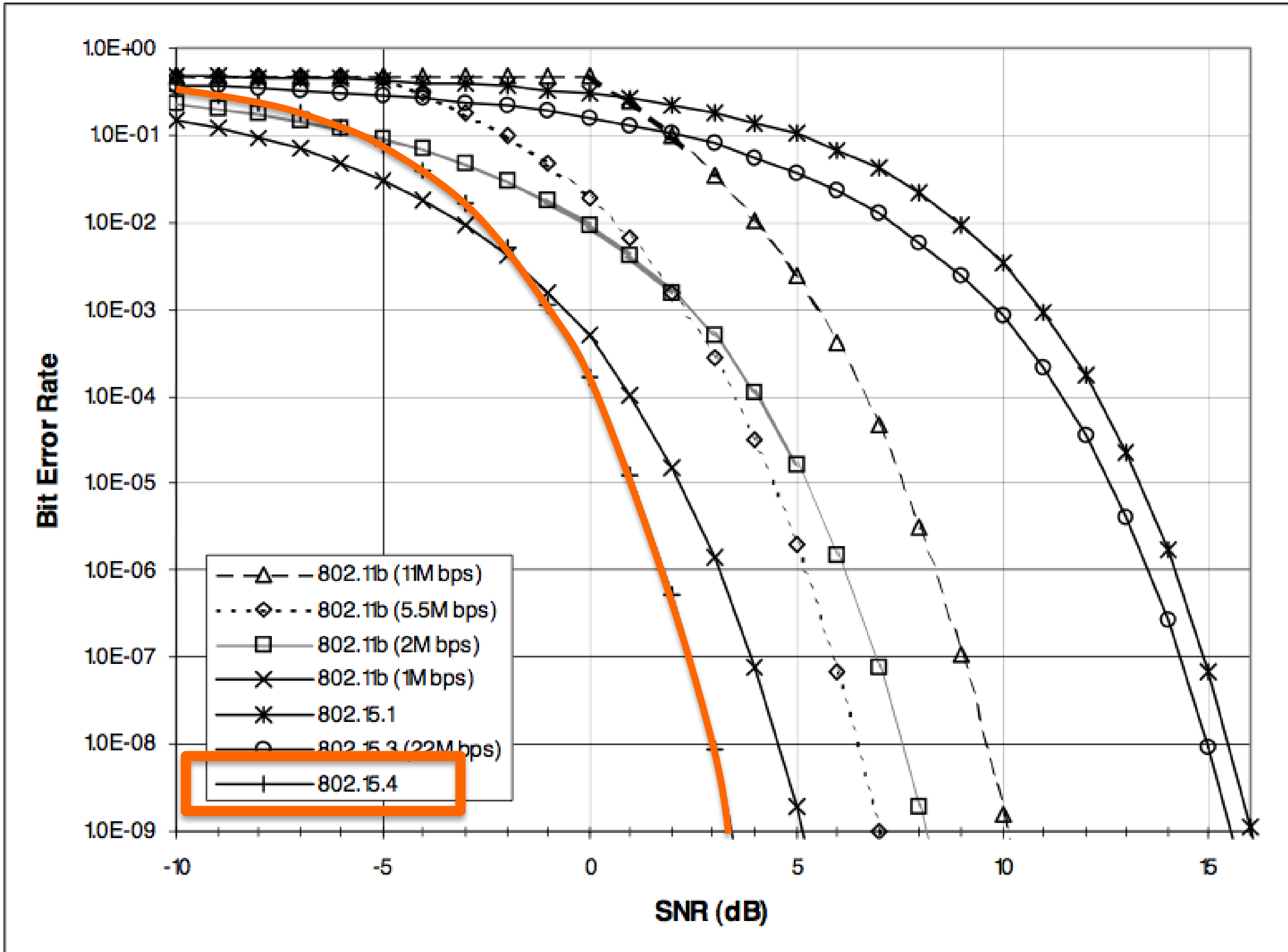


Figure E.2—BER Results for IEEE 802.11, IEEE 802.15.1, IEEE P802.15.3 and IEEE 802.15.4

SINR vs. BER Fundamentals

- Higher SINR means lower BER.
  - This means *I* and *N* remaining equal we want to increase *S* for lower BER. *S* and *N* remaining equal we want to reduce I.
- Higher bit rate means higher BER.
- Packer error rate (PER) depends also on packet size. Larger packet size will have higher PER.

Concept of Path Loss

- Any transmitted signal loses power rapidly with distance.
  - This is a key problem with wireless channel.
- Thus, following the concepts that we learnt, both S and I loses power with distance.

Modeling Path Loss

- Large scale path loss
  - Models average channel condition
- Small scale path loss
  - Models short term variations due to a phenomenon called "fading."
- We limit ourselves to large scale losses.

Free Space Path Loss Model

- Simplest model – assumes free space. Modeled using *Friis equation*.
- Power decays as inverse of square of distance *d* from transmitter

$$P_r \propto \frac{P_t}{d^2} \quad \text{or} \quad P_r = K\frac{P_t}{d^2}$$

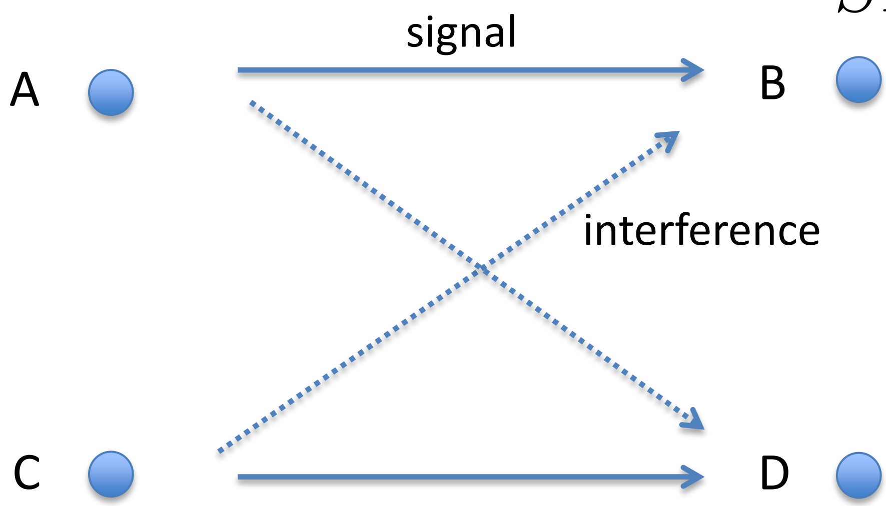
- The constant *K* is related to wavelength λ and transmit and receive antenna gains G_t and G_r

$$K = G_t G_r \left(\frac{\lambda}{4\pi}\right)^2$$

What does it mean by a "wireless link"?

- It is wireless. Where is the "link"?
- Wireless link is a logical concept in most part.
- Assume, for a given bit rate/modulation BER < Threshold to keep PER at acceptable level.
- This will define a Threshold on SINR (say, β).
- We say that there is a link between Tx and Rx if SINR $\geq \beta$.
- This is sometimes called "SINR Threshold Model".

Example



$$SINR = \frac{\frac{KP_A}{d_{AB}^{\alpha}}}{N + \frac{KP_C}{d_{CB}^{\alpha}}}$$

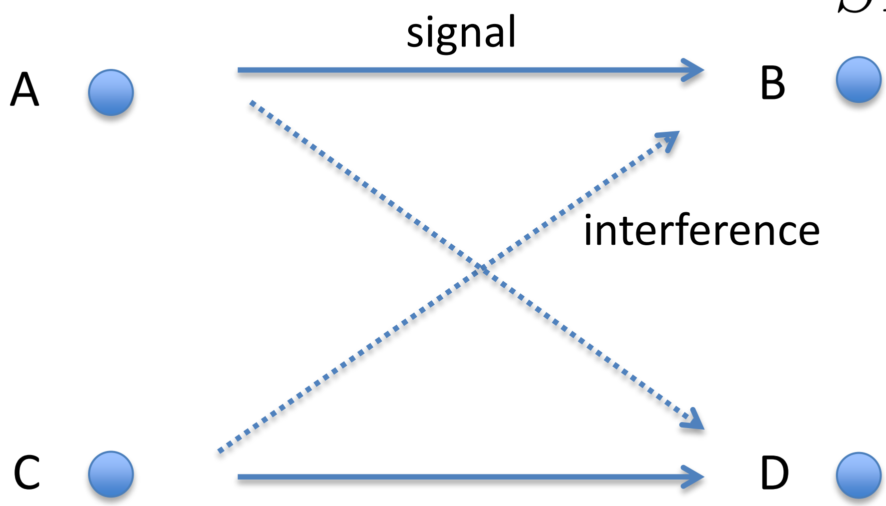
$$\alpha = 2$$

$$SINR = \frac{\frac{KP_C}{d_{CD}^{\alpha}}}{N + \frac{KP_A}{d_{AD}^{\alpha}}}$$

P_A etc are transmit powers. d_{AB} are distances. Log-distance path loss model is used. There is a link between AB or CD if the corresponding SINR

. $\geq \beta$

Example



$$SINR = \frac{\frac{KP_A}{d_{AB}^{\alpha}}}{N + \frac{KP_C}{d_{CB}^{\alpha}}}$$

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$$SINR = \frac{\frac{KP_C}{d_{CD}^{\alpha}}}{N + \frac{KP_A}{d_{AD}^{\alpha}}}$$

If the SINR condition is not satisfied, we say that packets “collide.”
Avoiding or recovering from such collisions is a problem to be handled by the upper layer.