Random Access Techniques: ALOHA (cont.)

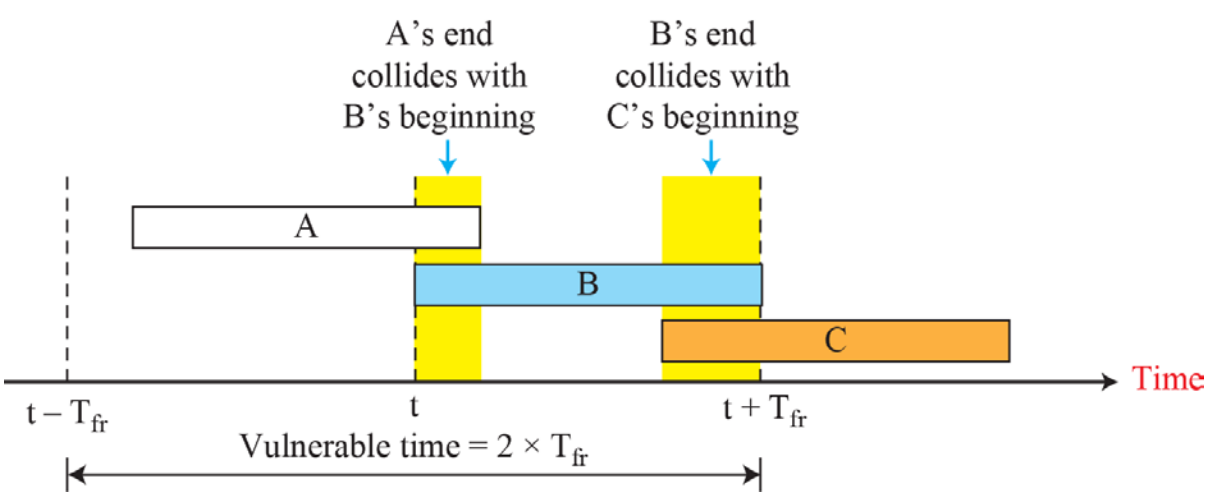
Example **[Aloha – avoiding collision]**

A pure ALOHA network transmits a 200-bit frame on a shared channel Of 200 kbps at time t_0. What is the requirement to make this frame collision free?

Solution:

Frame transmission time T_f = 200 bits / 2000 kbps = 1 msec.
Vulnerability period = 2 * 1 msec = 2 msec

Collision will be avoided if no other station start transmitting 1 msec before and during the transmission of this frame.

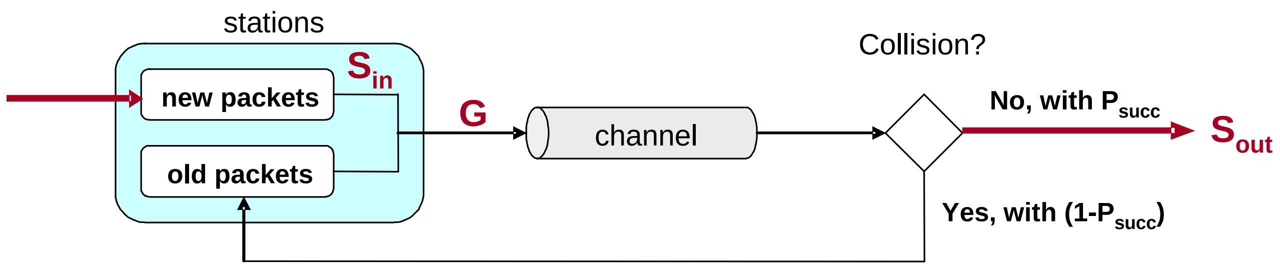


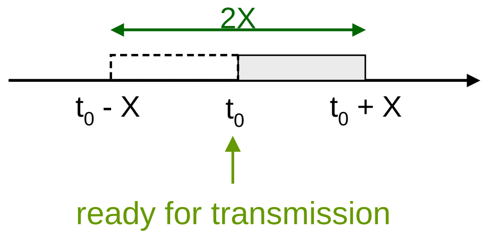
Throughput

- **definitions and assumptions:**
  - **S (S_{out}) – throughput: average # of successful frame transmiss. per *X* sec** (if network operates under 'stable conditions' $S_{out} = S_{in}$, where S_{in} - arrival rate of new frames to the system)
  - **G – load – average # of overall transmission attempts! per X sec**
  - **P_{succ} – probability of a successful frame transmission**

$$S = P_{succ} \cdot G$$

  - **How to find P_{succ}? – suppose a frame is ready for transmission at time t_0 – frame will be transmitted successfully if no other frame attempts transmission X sec before and after t_0**
  - **random backoff spreads retransmissions so that frame transmission (arrivals) are equally likely at any instant in time – Poisson process!!!**





Random Access Techniques: ALOHA (cont.)

- **if general, if frame arrivals are <u>equally likely</u> at any instant in time, and arrivals occur at an average rate of λ [arrivals per sec]**

Poisson process →

$$P[\text{k arrivals in T seconds}] = \frac{(\lambda T)^k}{k!} e^{-\lambda T}$$

- **to get [arrivals per second] λ is calculated as λ=G/X, while interval of interest is T=2X, hence**

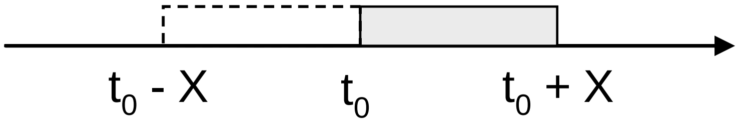
$$P[\text{k transmissions in 2X seconds}] = \frac{(2G)^k}{k!} e^{-2G}$$

- **thus, probability of successful transmission (no other transmission in T=2X seconds) is:**

$$P_{succ} = P[\text{0 transmissions in 2X seconds}] = e^{-2G}$$

and throughput

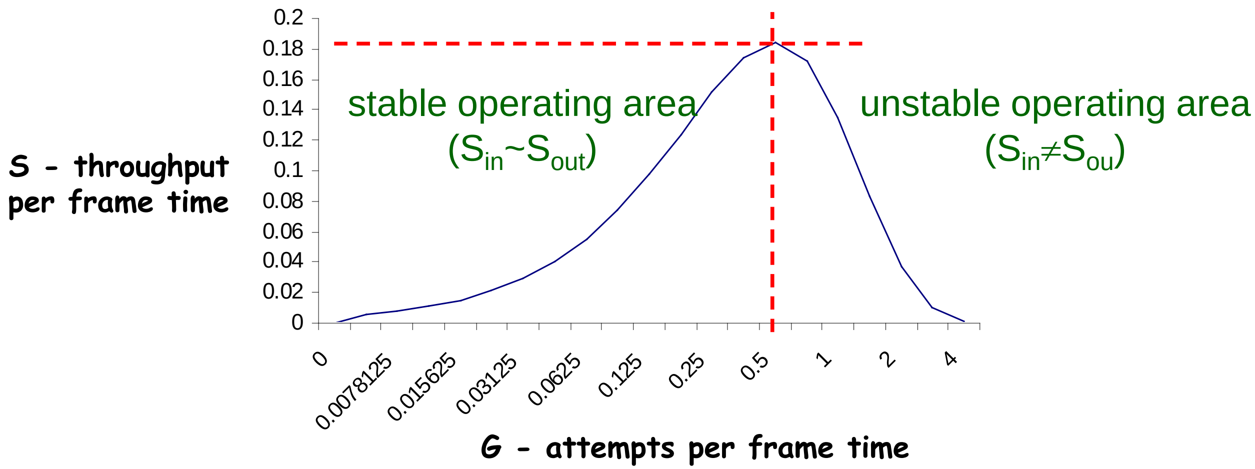
$$S = G \cdot P_{succ} = G \cdot e^{-2G}$$



Random Access Techniques: ALOHA (cont.)

S vs. G in Pure ALOHA

- **NOTE: our analysis assumed that <u>many nodes</u> share a common channel & have comparable transmiss. rates** **(if only 1 node uses the medium, S=1)**
- **initially, as G increases S increases until it reaches S_{max} – after that point the network enters 'unstable operating conditions' in which collisions become more likely and the number of backlogged stations increases (consequently, $S_{in} > S_{out}$)**
- **max throughput of ALOHA (S_{max} = 0.184) occurs at G=0.5, which corresponds to a total arrival rate of 'one frame per vulnerable period'**
- **<u>S_{max} = 0.184 ⇒ max ALOHA throughput = 18% of channel capacity</u>**



18% of channel utilization, with Aloha, is not encouraging.
But, with everyone transmitting at will we could hardly expect a 100% success rate.

Random Access Techniques: ALOHA (cont.)

Example **[Aloha]**

A pure ALOHA network transmits 200-bits frames on a shared channel of 200 kbps.

What is the throughput of this system if all stations together produce 1000 frames per second?

Solution:

Throughput of pure ALOHA:

$$S = G \cdot e^{-2G} \frac{\text{frames}}{\text{frame time}}$$

G = 1000 [frames / second], but we need it in [frames / frame time]

Frame time X = 200 bits / 200 kbps = 1 msec

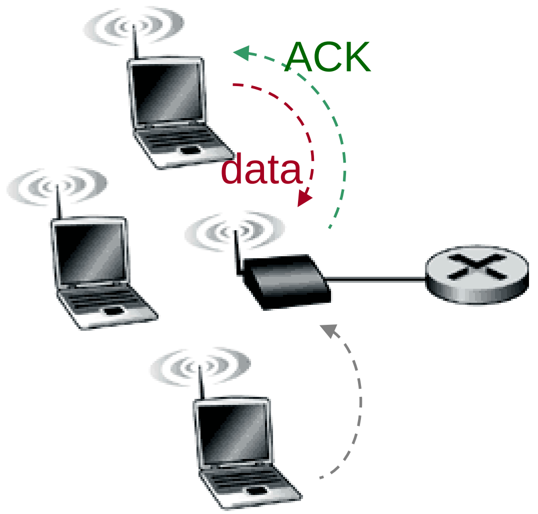
G = 1000 [frames / 1000 frame times] = 1 [frame / frame time]

Hence,

$$S(G=1) = e^{-2} = 0.135 \frac{\text{frames}}{\text{frame time}} = 0.135 \frac{\text{frames}}{1\text{msec}} = 135 \frac{\text{frames}}{\text{sec}}$$

Random Access Techniques: ALOHA (cont.)

Example [Aloha]



a) What is the vulnerable period (in milliseconds) of a pure ALOHA broadcast system with R=50-kbps wireless channel, assuming 1000-byte frames.

b) What is the maximum possible throughput S of such a channel (system), in kbps?

---

a) (frame transmission time =) X = 1000 bytes / 50 kbps = 8000 bits / 50 kbps
$\Rightarrow$ X = 160 milliseconds

vulnerable period = 2*X = 320 milliseconds

b) We do not have enough information to determine G. The best we can do …
From theory, max throughput = 0.18 * R = 0.18 * 50 kbps = 9.179 kbps

Random Access Techniques: Slotted ALOHA

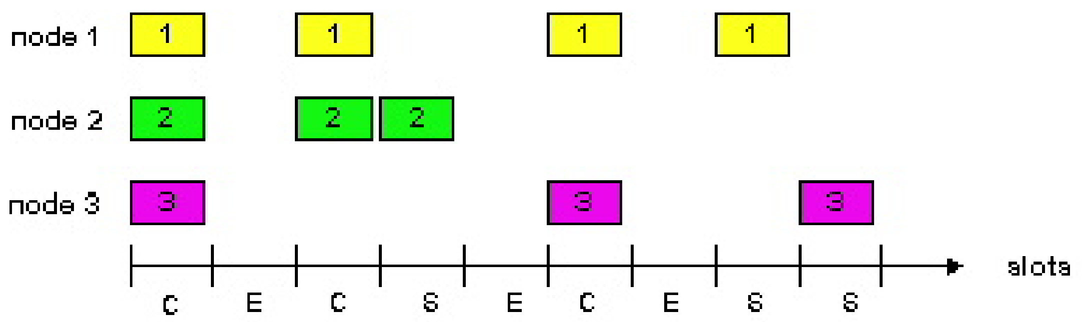
Slotted ALOHA – "improved ALOHA", with reduced probability of collision

- **assumptions:**
  - time is divided into slots of size X=L/R (one frame time)
  - nodes start to transmit only at the beginning of a slot
  - nodes are synchronized so that each node knows when the slots begin

- **operation:**

  1) when node has a fresh frame to send, it waits until next frame slot and transmits

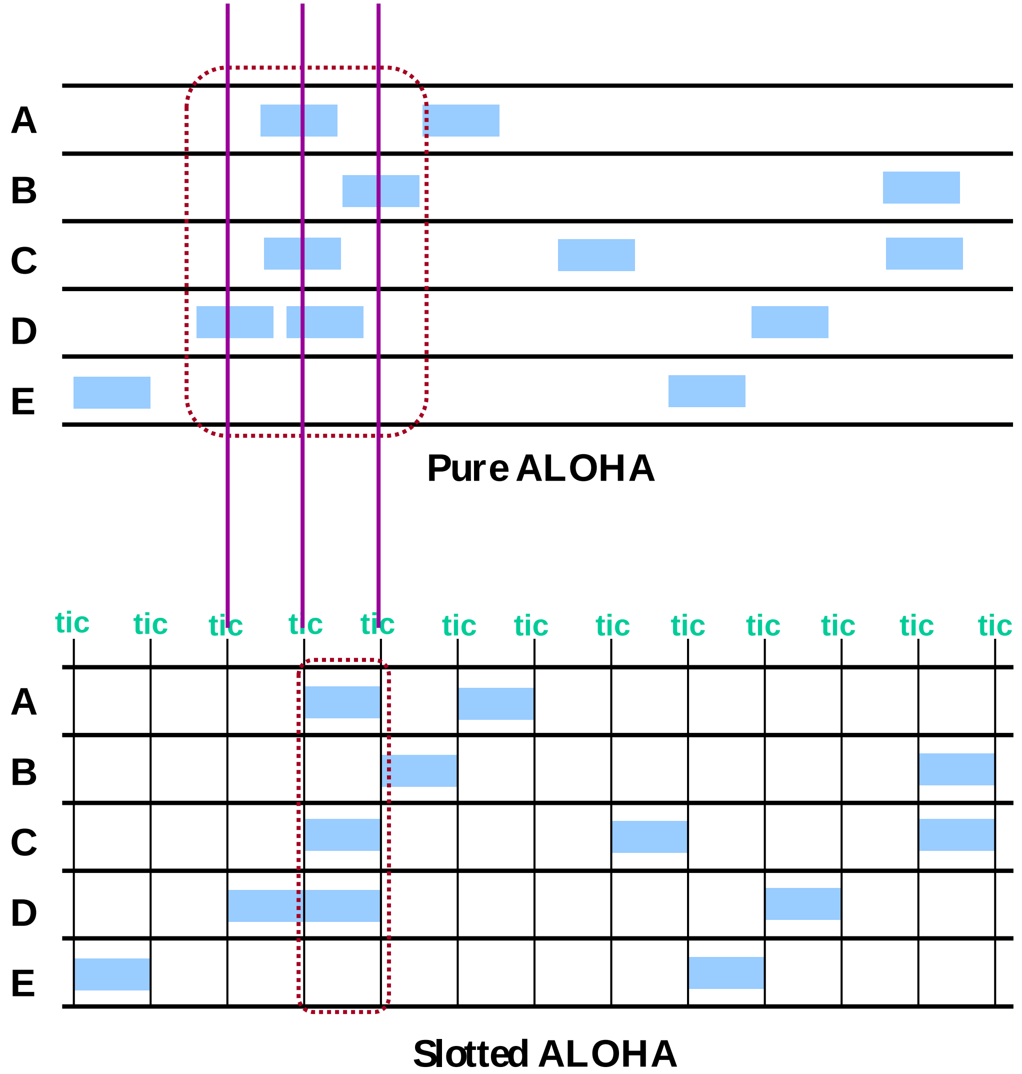
  3) if there is a collision, node retransmits the frame after a backoff-time (backoff-time = multiples of time-frames)



http://www.invocom.et.put.poznan.pl/~invocom/C/P1-4/p1-4_en/p1-4_3_8.htm

Random Access Techniques: Slotted ALOHA (cont.)

Example [Aloha vs. Slotted Aloha]



Random Access Techniques: Slotted ALOHA (cont.)

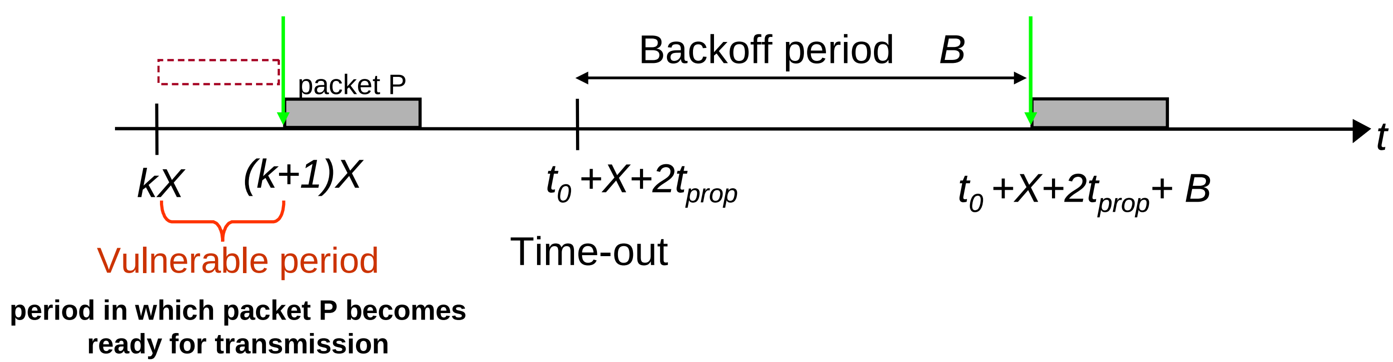
Vulnerable Period of Slotted ALOHA

- **consider one arbitrary packet P that becomes ready for transmission at some time t during the time slot [k, k+1]**
- **packet P will be transmitted successfully if no other packet becomes available for transmission during the same time slot**

vulnerable period = [t_0 – X, t_0]

$$P_{succ} = P[0 \text{ arrivals in X seconds}] = e^{-G}$$

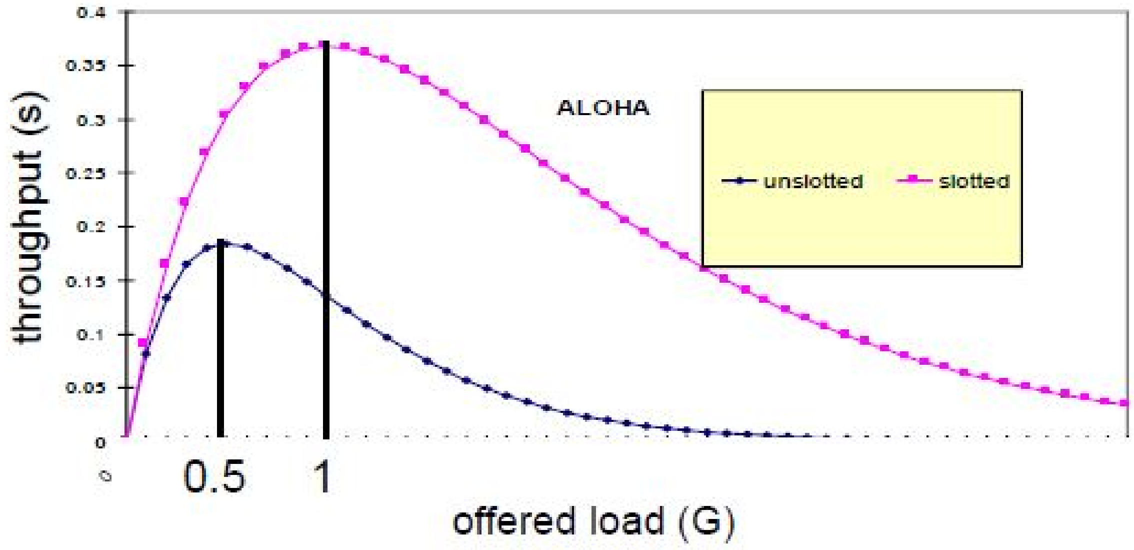
$$S = G \cdot P_{succ} = G \cdot e^{-G}$$



Random Access Techniques: Slotted ALOHA (cont.)

S vs. G in Slotted ALOHA

- max throughput of Slotted ALOHA (S_{max} = 0.36) occurs at G=1, which corresponds to a total arrival rate of 'one frame per vulnerable period'
- S_{max} = 0.36 $\Rightarrow$ max Slotted ALOHA throughput = 36% of actual channel capacity



Slotted ALOHA vs. Pure ALOHA

- slotted ALOHA reduces vulnerability to collision, but also adds a waiting period for transmission
- if contention is low, it will prevent very few collisions, & delay many of the (few) packets that are sent

Random Access Techniques: Slotted ALOHA (cont.)

Example [slotted Aloha]

Measurements of slotted ALOHA channel with an infinite number of users show that 10% of the slots are idle.

a) What is the channel load, G?

b) What is the throughput, S?

c) Is the channel underloaded or overloaded?

---

a) 10% of slots idle ⇒

frame will be successfully transmitted if sent in those 10% of slots ⇒

$P_{succ} = 0.1$

According to theory, $P_{succ} = e^{-G}$ ⇒ $G = -\ln(P_{succ}) = -\ln(0.1) = 2.3$

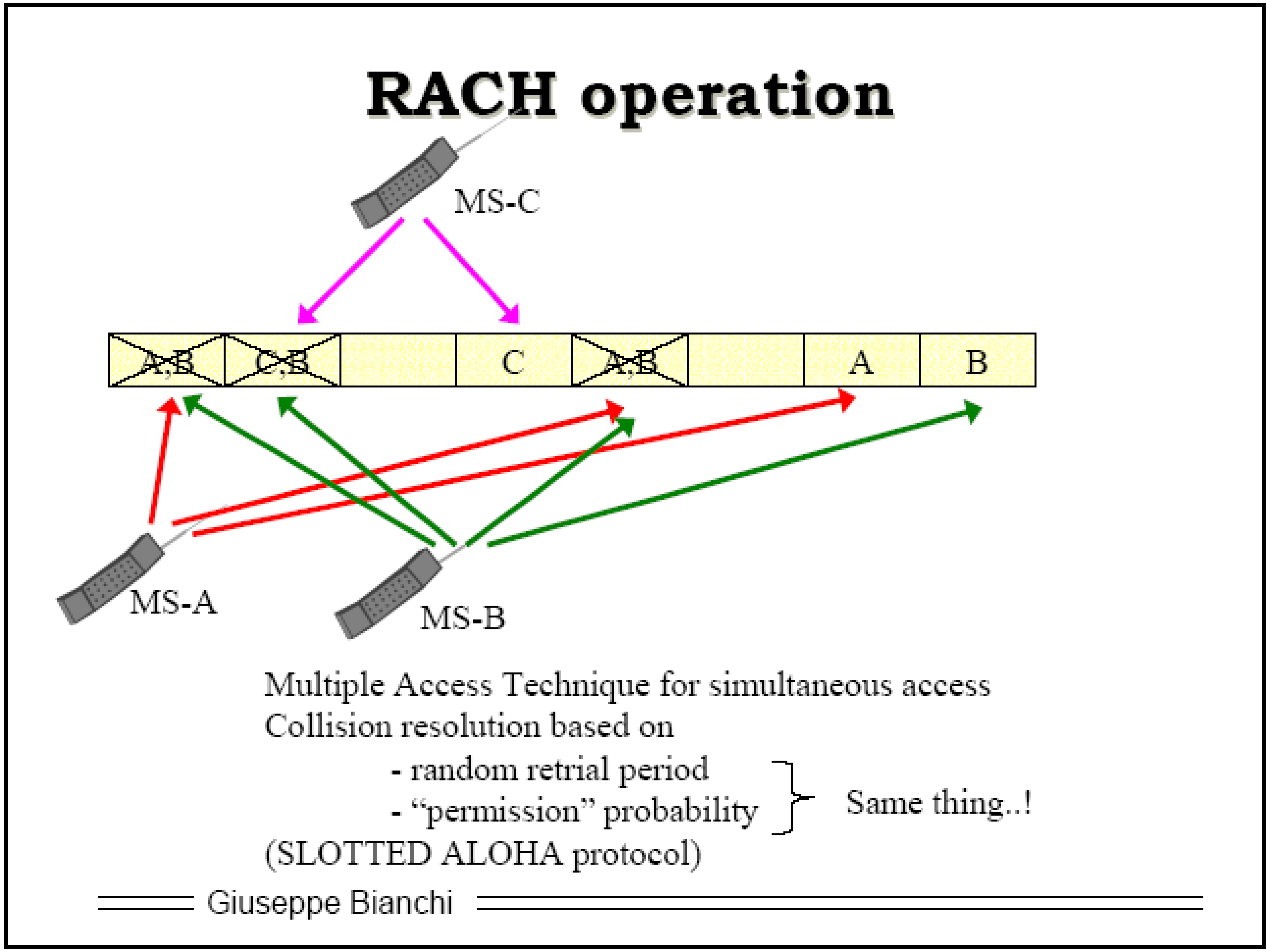
b) According to theory, $S = P_{succ} * G = G * e^{-G}$

as $G=2.3$ and $e^{-G}=0.1$ ⇒ $S = 0.23$

c) Whenever G>1, the channel is overloaded, so it is overloaded in this case.

Random Access Techniques: Slotted ALOHA (cont.)

Example [slotted Aloha in cellular (GSM) systems]



http://www.tti.unipa.it/mat_bianchi/rm/04.pdf

Random Access Techniques: ALOHA (cont.)

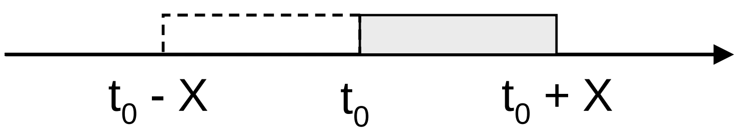
- **if general, if frame arrivals are <u>equally likely</u> at any instant in time, and arrivals occur at an average rate of λ [arrivals per sec]**

Poisson process →

$$P[\text{k arrivals in T seconds}] = \frac{(\lambda T)^k}{k!} e^{-\lambda T}$$

- **to get [arrivals per second], λ is calculated as $\lambda = G/X$**

- **to avoid collision, there should be only 1 transmission in the interval X starting at t_0 AND 0 transmissions in the interval X preceding t_0**



$$P_1 = P[\text{1 transmissions in X seconds}] = \frac{\left(\frac{G}{X} \cdot X\right)^1}{1!} \cdot e^{-\frac{G}{X} \cdot X} = G \cdot e^{-G}$$

$$P_2 = P[\text{0 transmissions in X seconds}] = e^{-G}$$

$$P_{succ} = P_1 \cdot P_2 = G \cdot e^{-2G}$$

$$P_{succ} = P_1 \cdot P_2 = G \cdot e^{-2G}$$