

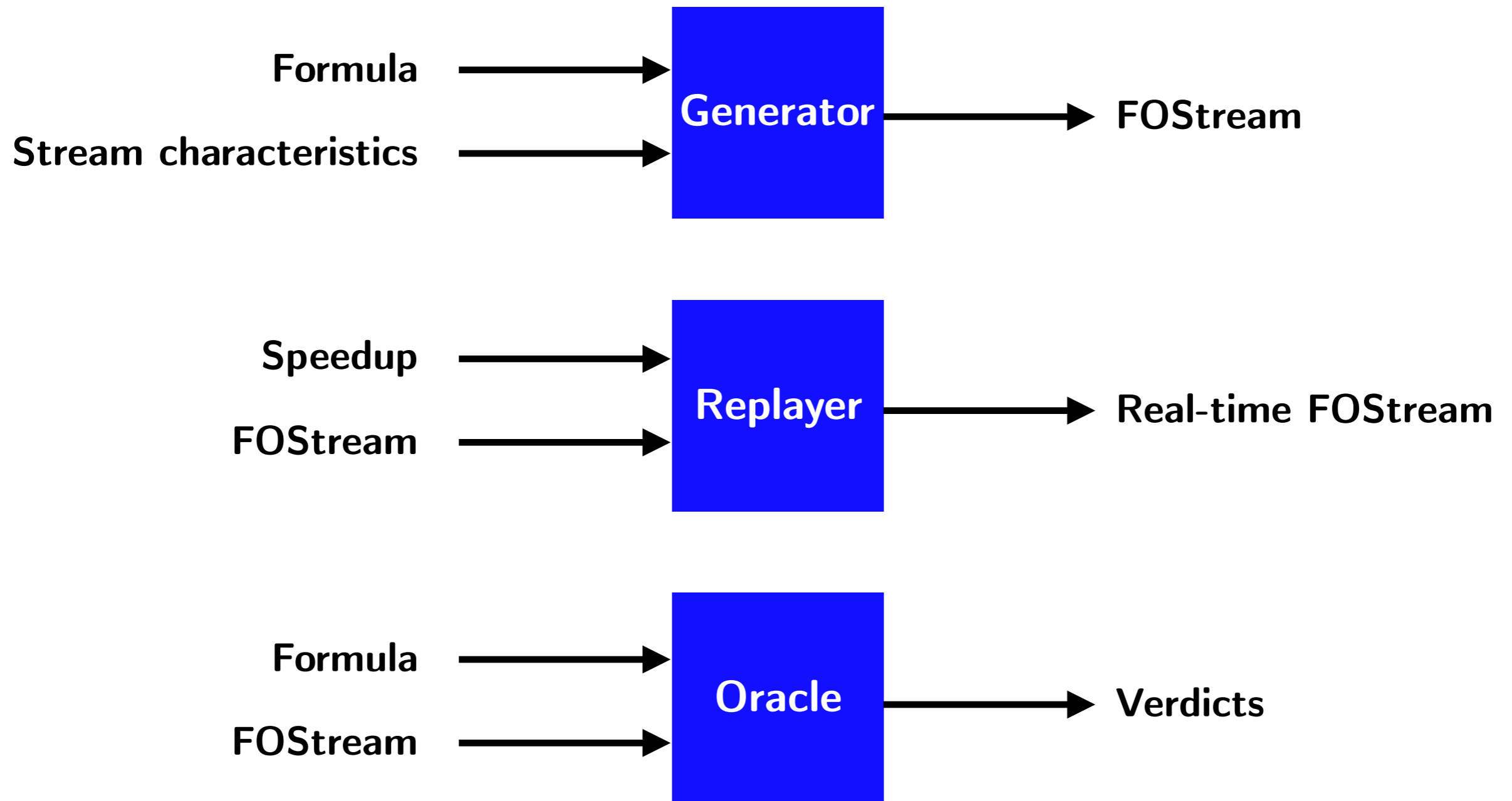
FOStreams: Stream Characteristics for First-Order Monitoring

Joshua Schneider

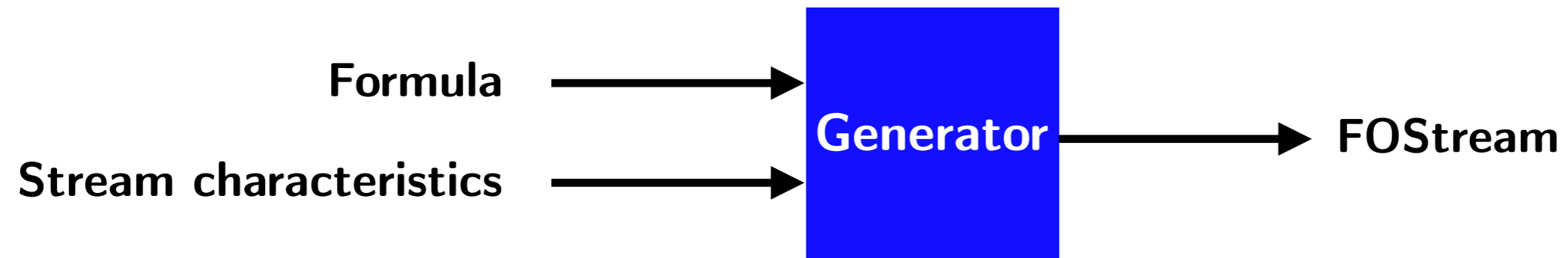
Srđan Krstić

ETH Zürich

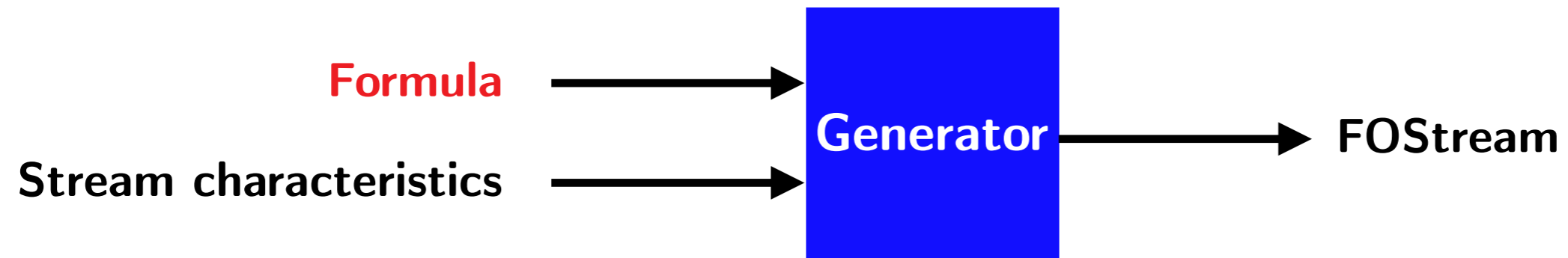
FOStreams Benchmark Overview



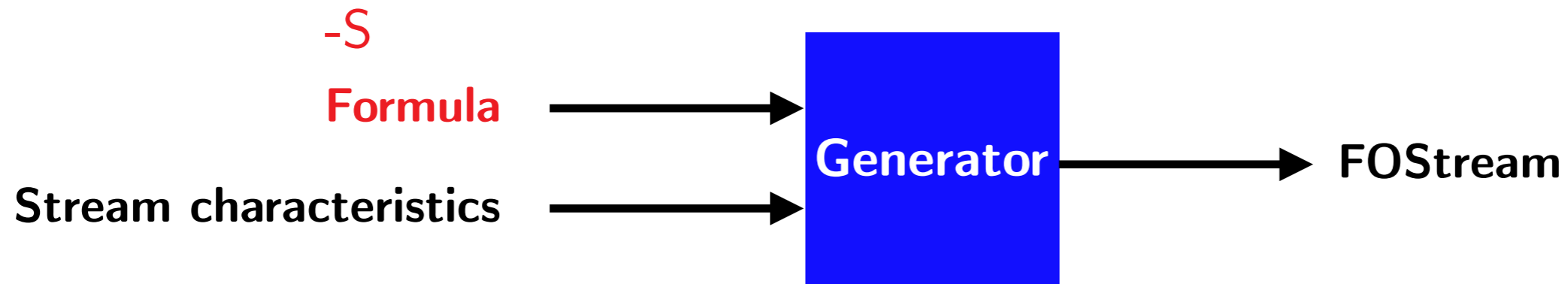
FOStreams Generator



FOStreams Generator

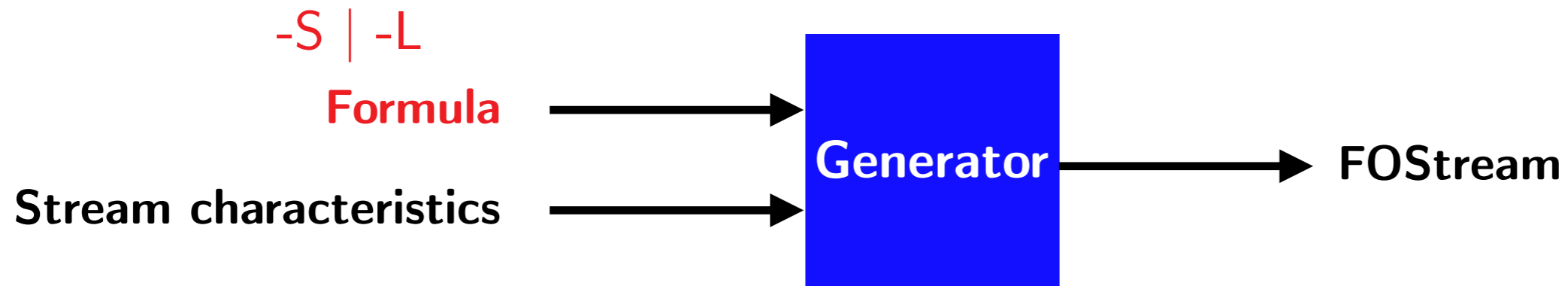


FOStreams Generator



$$\square \forall v. \forall x. \forall y. \forall z. \left(\blacklozenge_{[0,10)} A(v, x) \right) \wedge B(v, y) \rightarrow \square_{[0,10)} \neg C(v, z)$$

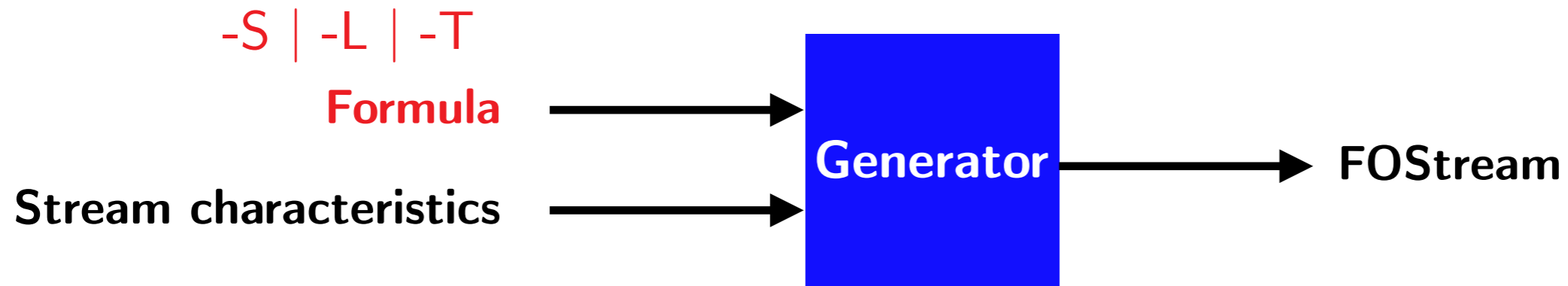
FOStreams Generator



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FOStreams Generator

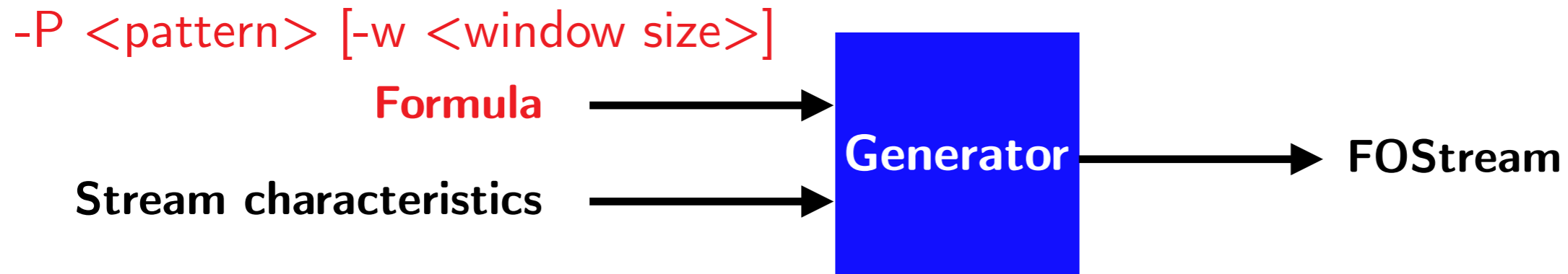


$$\square \forall v. \forall x. \forall y. \forall z. \left(\blacklozenge_{[0,10)} A(v, x) \right) \wedge B(v, y) \rightarrow \square_{[0,10)} \neg C(v, z)$$

$$\square \forall v. \forall x. \forall y. \forall z. \left(\blacklozenge_{[0,10)} A(v, x) \right) \wedge B(x, y) \rightarrow \square_{[0,10)} \neg C(y, z)$$

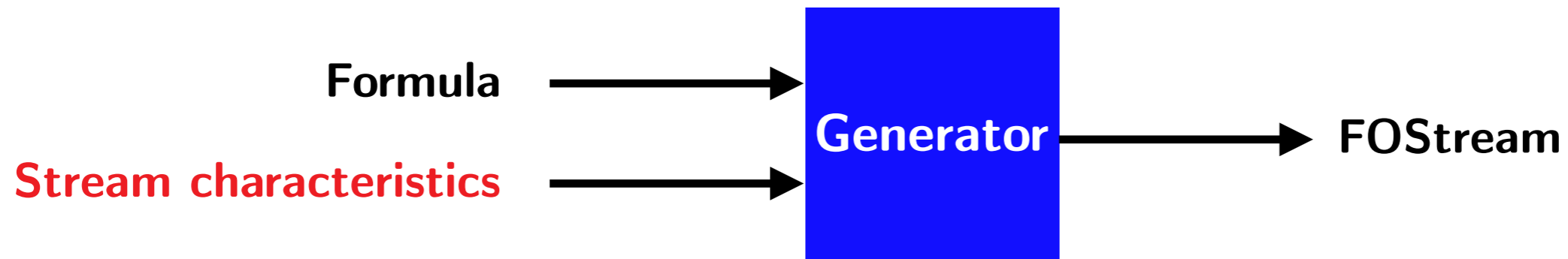
$$\square \forall x. \forall y. \forall z. \left(\blacklozenge_{[0,10)} A(x, y) \right) \wedge B(y, z) \rightarrow \square_{[0,10)} \neg C(z, x)$$

FOStreams Generator



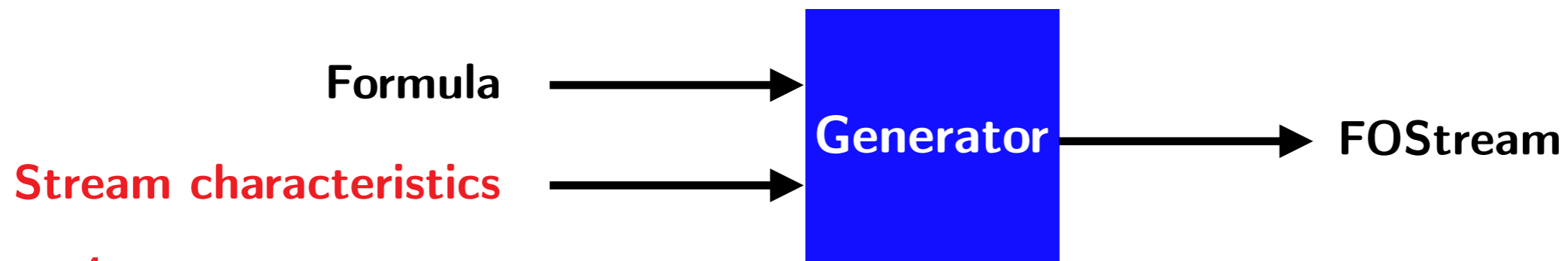
$$\square \forall \vec{x}. \left(\blacklozenge_{[0,w)} A(\vec{x}_A) \right) \wedge B(\vec{x}_B) \rightarrow \square_{[0,w)} \neg C(\vec{x}_C)$$

FOStreams Generator



C, $tp=0$, $ts=0$, $x_0=...$, $x_1=...$, ...
B, $tp=0$, $ts=0$, $x_0=...$, $x_1=...$, ...
B, $tp=1$, $ts=0$, $x_0=...$, $x_1=...$, ...
C, $tp=1$, $ts=0$, $x_0=...$, $x_1=...$, ...
A, $tp=2$, $ts=1$, $x_0=...$, $x_1=...$, ...
A, $tp=2$, $ts=1$, $x_0=...$, $x_1=...$, ...
A, $tp=3$, $ts=1$, $x_0=...$, $x_1=...$, ...
B, $tp=3$, $ts=1$, $x_0=...$, $x_1=...$, ...
B, $tp=4$, $ts=2$, $x_0=...$, $x_1=...$, ...
A, $tp=4$, $ts=2$, $x_0=...$, $x_1=...$, ...
A, $tp=5$, $ts=2$, $x_0=...$, $x_1=...$, ...
B, $tp=5$, $ts=2$, $x_0=...$, $x_1=...$, ...

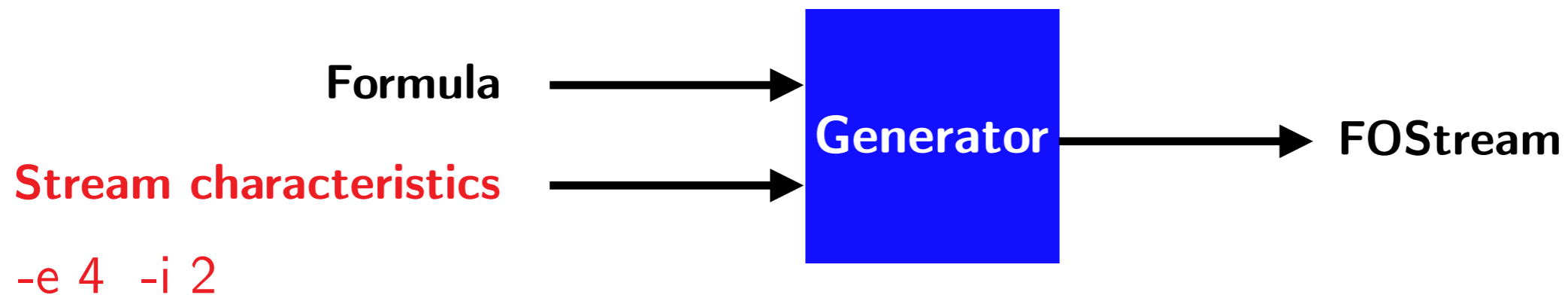
FOStreams Generator



-e 4

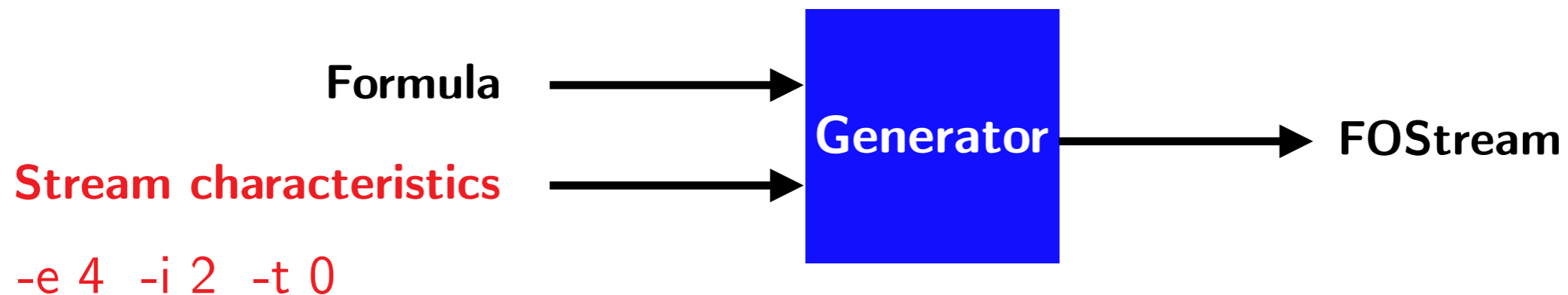
C, tp=0, ts=0, x0=..., x1=..., ...
B, tp=0, ts=0, x0=..., x1=..., ...
B, tp=1, ts=0, x0=..., x1=..., ...
C, tp=1, ts=0, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=3, ts=1, x0=..., x1=..., ...
B, tp=3, ts=1, x0=..., x1=..., ...
B, tp=4, ts=2, x0=..., x1=..., ...
A, tp=4, ts=2, x0=..., x1=..., ...
A, tp=5, ts=2, x0=..., x1=..., ...
B, tp=5, ts=2, x0=..., x1=..., ...

FOStreams Generator



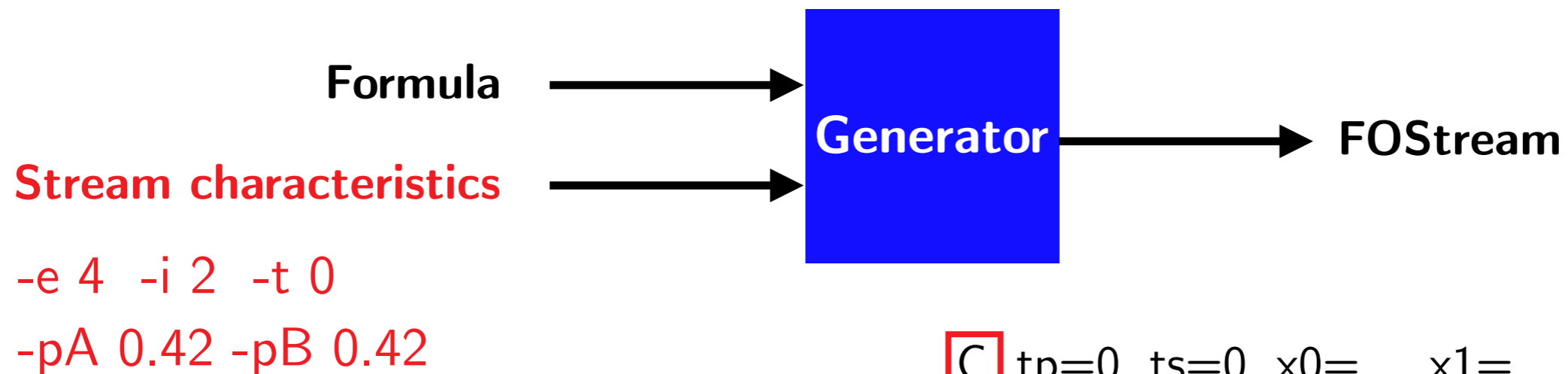
C, tp=0, ts=0, x0=..., x1=..., ...
B, tp=0, ts=0, x0=..., x1=..., ...
B, tp=1, ts=0, x0=..., x1=..., ...
C, tp=1, ts=0, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=3, ts=1, x0=..., x1=..., ...
B, tp=3, ts=1, x0=..., x1=..., ...
B, tp=4, ts=2, x0=..., x1=..., ...
A, tp=4, ts=2, x0=..., x1=..., ...
A, tp=5, ts=2, x0=..., x1=..., ...
B, tp=5, ts=2, x0=..., x1=..., ...

FOStreams Generator



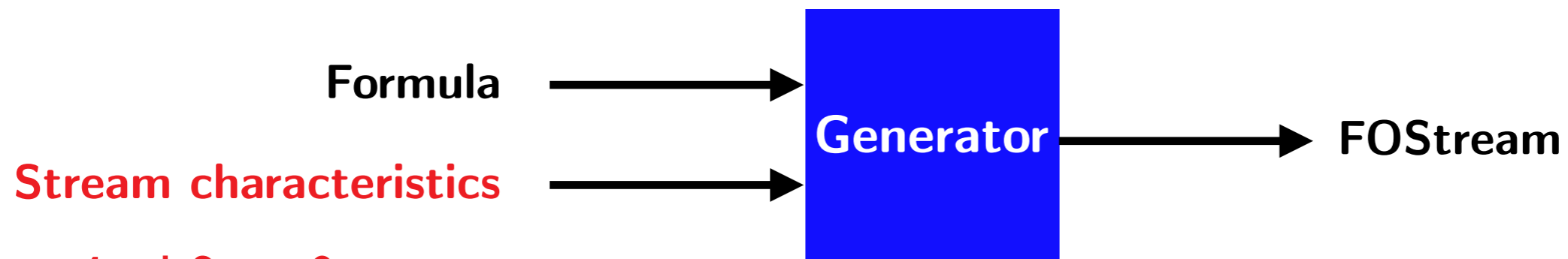
C, tp=0, ts=0, x0=..., x1=..., ...
B, tp=0, ts=0, x0=..., x1=..., ...
B, tp=1, ts=0, x0=..., x1=..., ...
C, tp=1, ts=0, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=3, ts=1, x0=..., x1=..., ...
B, tp=3, ts=1, x0=..., x1=..., ...
B, tp=4, ts=2, x0=..., x1=..., ...
A, tp=4, ts=2, x0=..., x1=..., ...
A, tp=5, ts=2, x0=..., x1=..., ...
B, tp=5, ts=2, x0=..., x1=..., ...

FOStreams Generator



C, tp=0, ts=0, x0=..., x1=..., ...
B, tp=0, ts=0, x0=..., x1=..., ...
B, tp=1, ts=0, x0=..., x1=..., ...
C, tp=1, ts=0, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=3, ts=1, x0=..., x1=..., ...
B, tp=3, ts=1, x0=..., x1=..., ...
B, tp=4, ts=2, x0=..., x1=..., ...
A, tp=4, ts=2, x0=..., x1=..., ...
A, tp=5, ts=2, x0=..., x1=..., ...
B, tp=5, ts=2, x0=..., x1=..., ...

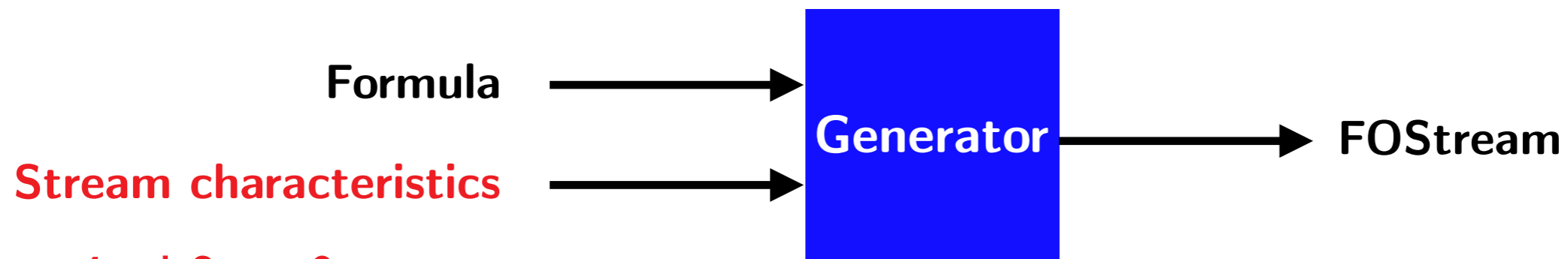
FOStreams Generator



-e 4 -i 2 -t 0
-pA 0.42 -pB 0.42
-x 0.1

C, tp=0, ts=0, x0=..., x1=..., ...
B, tp=0, ts=0, x0=..., x1=..., ...
B, tp=1, ts=0, x0=..., x1=..., ...
C, tp=1, ts=0, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=3, ts=1, x0=..., x1=..., ...
B, tp=3, ts=1, x0=..., x1=..., ...
B, tp=4, ts=2, x0=..., x1=..., ...
A, tp=4, ts=2, x0=..., x1=..., ...
A, tp=5, ts=2, x0=..., x1=..., ...
B, tp=5, ts=2, x0=..., x1=..., ...

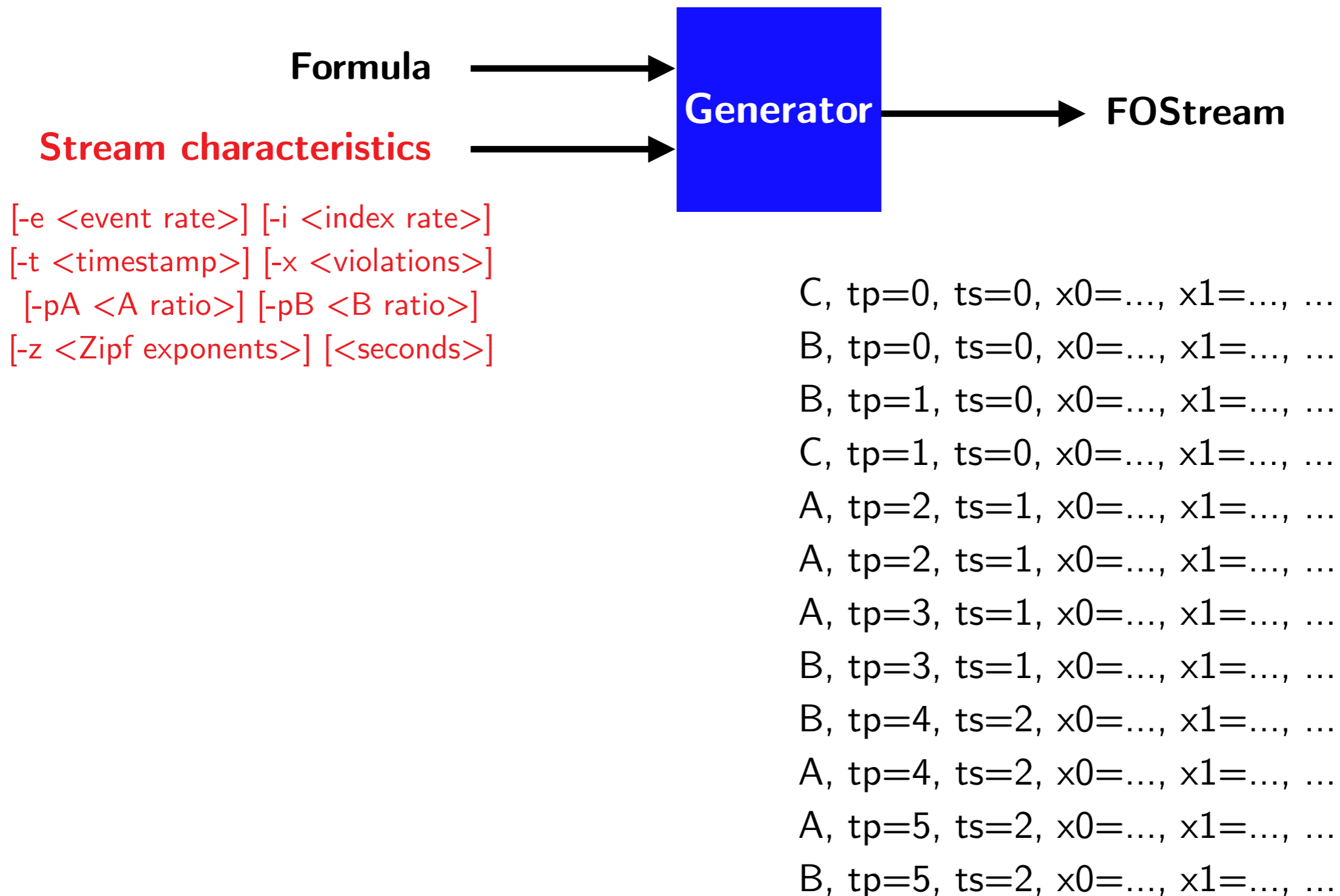
FOStreams Generator



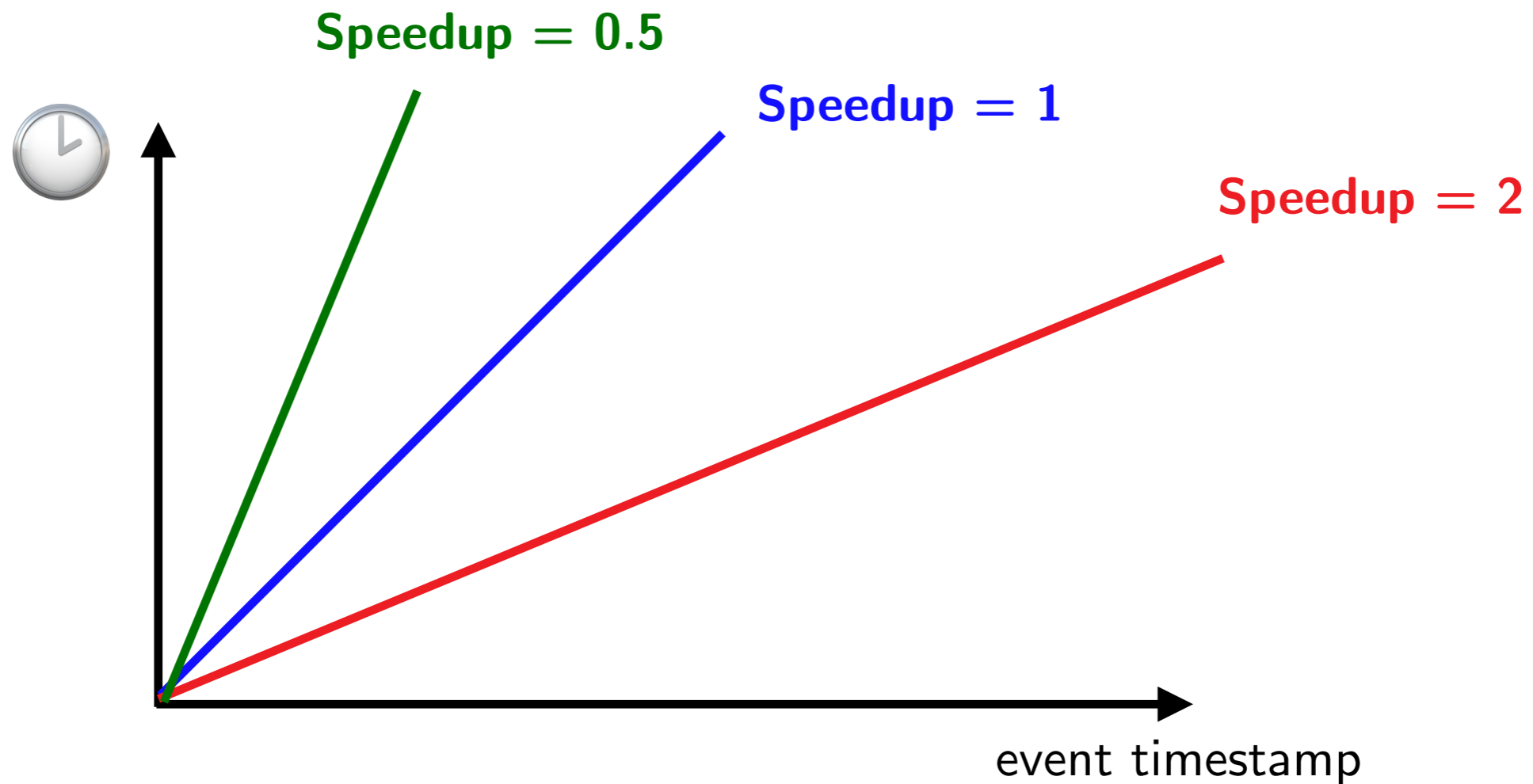
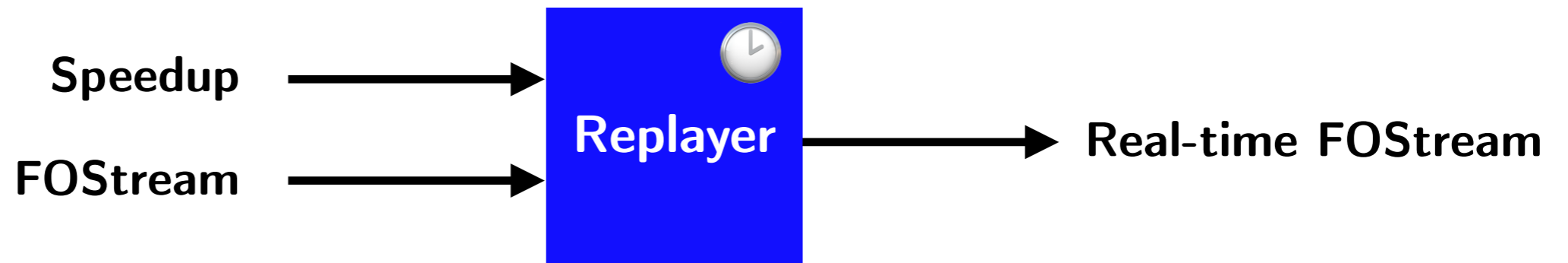
-e 4 -i 2 -t 0
-pA 0.42 -pB 0.42
-x 0.1
3

C, tp=0, ts=0, x0=..., x1=..., ...
B, tp=0, ts=0, x0=..., x1=..., ...
B, tp=1, ts=0, x0=..., x1=..., ...
C, tp=1, ts=0, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=2, ts=1, x0=..., x1=..., ...
A, tp=3, ts=1, x0=..., x1=..., ...
B, tp=3, ts=1, x0=..., x1=..., ...
B, tp=4, ts=2, x0=..., x1=..., ...
A, tp=4, ts=2, x0=..., x1=..., ...
A, tp=5, ts=2, x0=..., x1=..., ...
B, tp=5, ts=2, x0=..., x1=..., ...

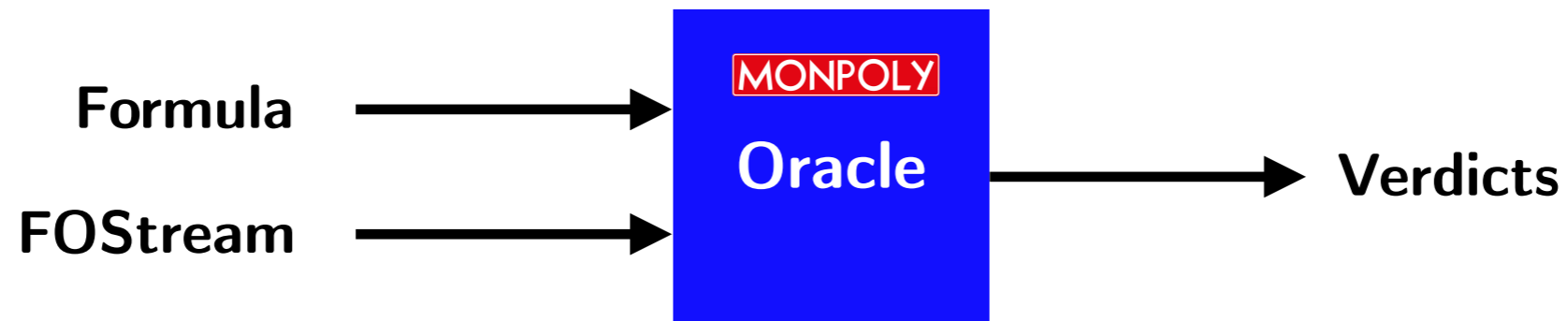
FOStreams Generator



FOSStreams Replayer



FOSStreams Oracle



$$\square \forall \vec{x}. \left(\blacklozenge_{[0,w)} A(\vec{x}_A) \right) \wedge B(\vec{x}_B) \rightarrow \square_{[0,w)} \neg C(\vec{x}_C)$$

Provides a list of triples (time-point, time-stamp, and assignments to \vec{x}) that violate the property.

Example (1)

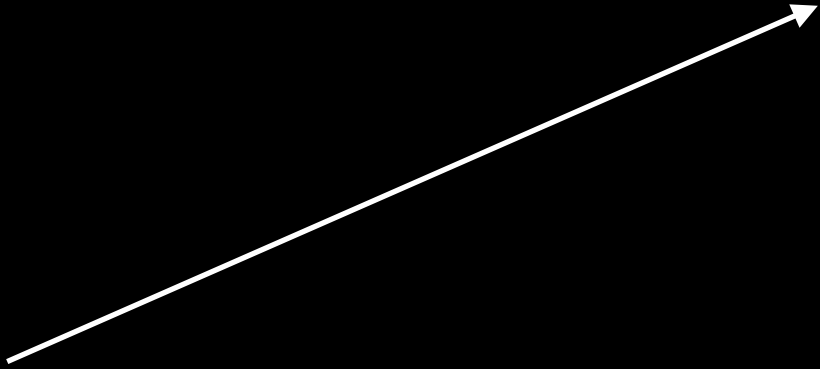
```
krle:~ krle$ alias bench="docker run -i infsec/benchmark"
krle:~ krle$ bench generator -S -e 4 -i 2 4
C, tp=0, ts=0, x0=373321178, x1=271925315
B, tp=0, ts=0, x0=355617325, x1=141336768
B, tp=1, ts=0, x0=977202503, x1=263078228
C, tp=1, ts=0, x0=782304503, x1=947669864
A, tp=2, ts=1, x0=78200211, x1=606967315
A, tp=2, ts=1, x0=870269555, x1=943366250
A, tp=3, ts=1, x0=551152087, x1=393602475
B, tp=3, ts=1, x0=870269555, x1=819702502
B, tp=4, ts=2, x0=454158356, x1=535982850
A, tp=4, ts=2, x0=583930965, x1=926246428
A, tp=5, ts=2, x0=194765226, x1=228331474
B, tp=5, ts=2, x0=105778896, x1=602083814
A, tp=6, ts=3, x0=248774096, x1=870342687
A, tp=6, ts=3, x0=95075313, x1=5126561
B, tp=7, ts=3, x0=78200211, x1=230151851
B, tp=7, ts=3, x0=912462831, x1=10932329
```

Example (2)

```
krle:~ krle$ time bench generator -S -e 4 -i 2 50 | bench replayer -a 5 > /dev/null  
  
real    0m11.351s  
user    0m0.184s  
sys     0m0.059s
```

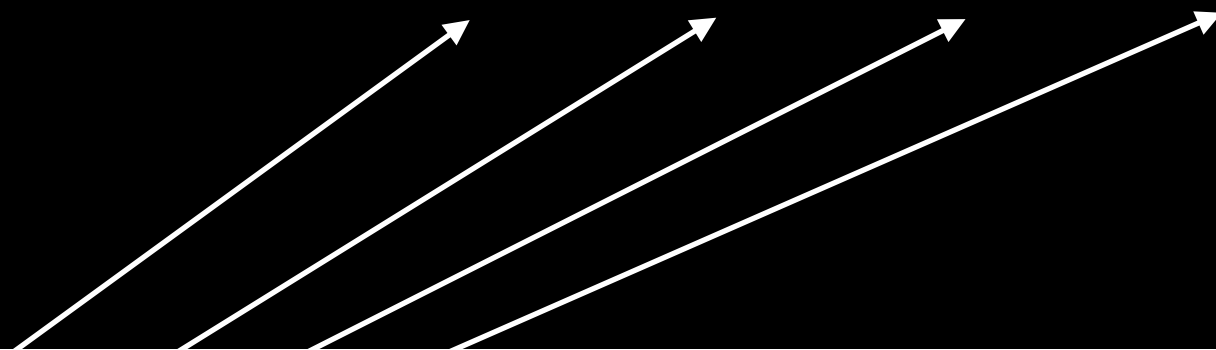
Example (3)

```
krle:~ krle$ bench generator -S -e 4 -i 2 -x 0.2 50 | bench replayer -m -a 10 | bench oracle -S  
@3. (time point 7): (905226255,544727831,226070484,811960572)  
@21. (time point 42): (422305181,899366530,60448027,556360567)  
@25. (time point 50): (617548455,149122710,413632294,725762786)  
@40. (time point 80): (752567723,326061056,281999085,290290427)  
@43. (time point 87): (15142361,254821830,831579120,86578035)
```



Example (3)

```
krle:~ krle$ bench generator -S -e 4 -i 2 -x 0.2 50 | bench replayer -m -a 10 | bench oracle -S  
@3. (time point 7): (905226255,544727831,226070484,811960572)  
@21. (time point 42): (422305181,899366530,60448027,556360567)  
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@43. (time point 87): (15142361,254821830,831579120,86578035)
```


$$\square \forall v. \forall x. \forall y. \forall z. \left(\blacklozenge_{[0,10)} A(v, x) \right) \wedge B(v, y) \rightarrow \square_{[0,10)} \neg C(v, z)$$