State Diagram

C++ Object Oriented Programming

Pei-yih Ting

NTOU CS

Contents

- Introduction to object states
- Interface vs. States
- Object with States
- Intuitive Implementation
- Explicit States
- State Diagram
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- Modification of the Design
- Design with the “State” Pattern

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  - A television set usually has a couple of control buttons, e.g. volume up/down, channel up/down, setup, power etc. However, not every button is responding at any moment, e.g. volume up/down do not function when **power is off**. Most of the buttons have a different set of functions when entering **setup mode**.

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2. The timing of messages to an object with various internal states is important and determines how an object responds.

3. Usually the states of an object cannot be observed directly from outside. The messages an object received up to now affect its current state and therefore its future behaviors.

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Intuitive Implementation

- Using *bool* variables to keep various kinds of states

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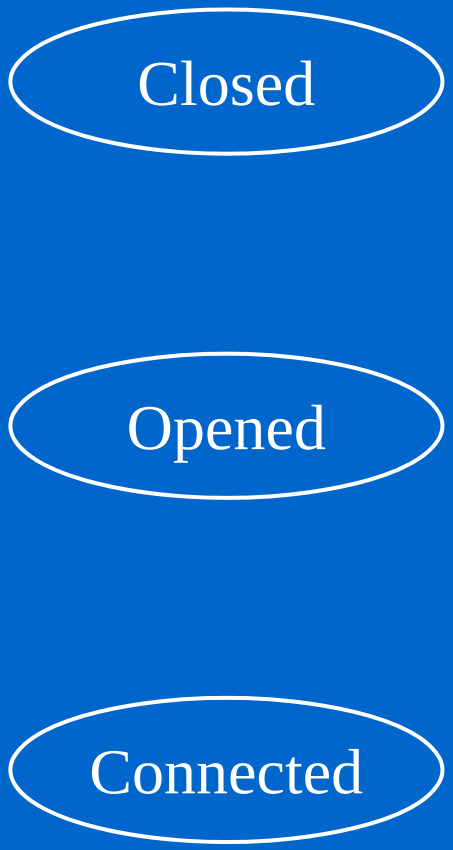
- There are six possible events (messages) to this object
  - **open**
  - **connect**
  - **read**
  - **write**
  - **disconnect**
  - **close**

State Diagram



Consider ALL possible events at the outgoing branches of each state.

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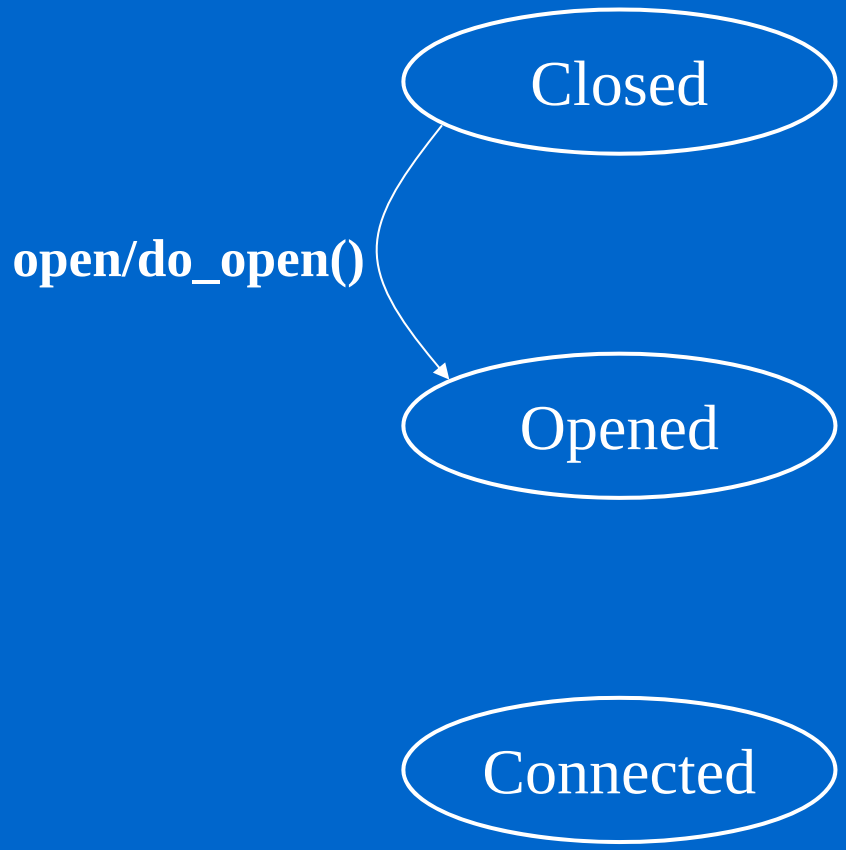

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Finite State Machine

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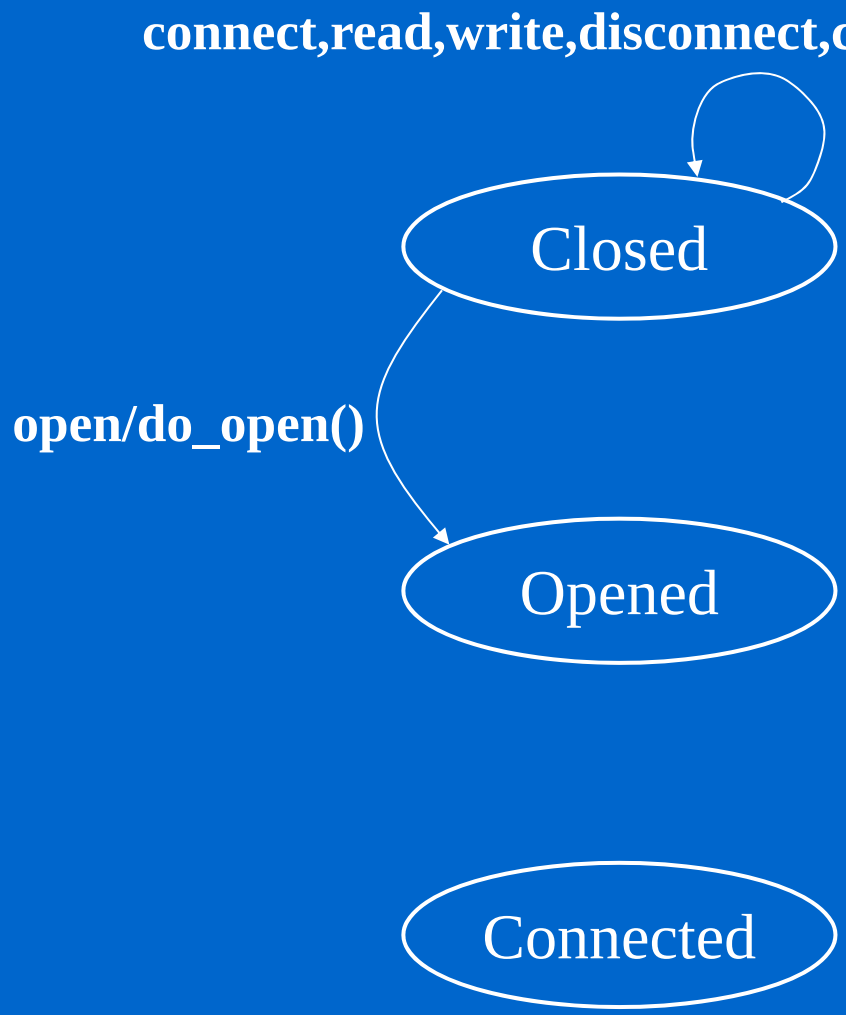

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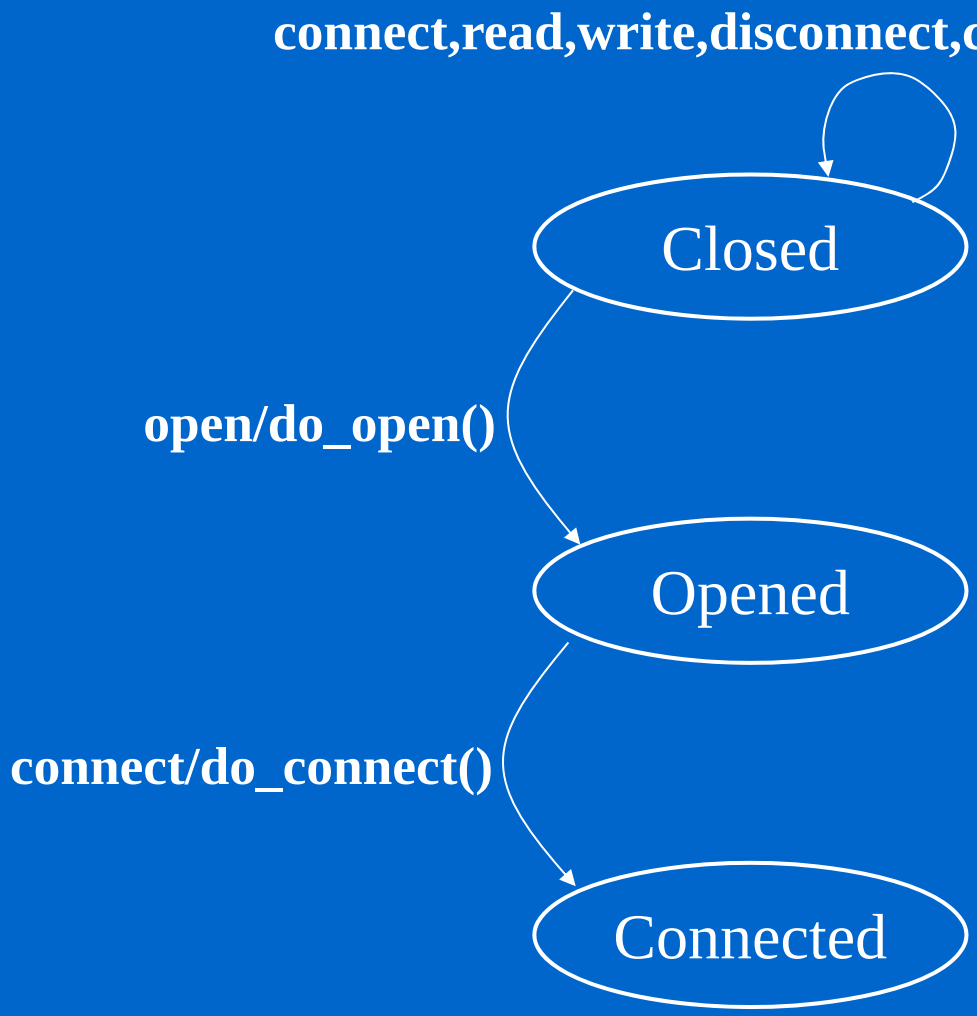

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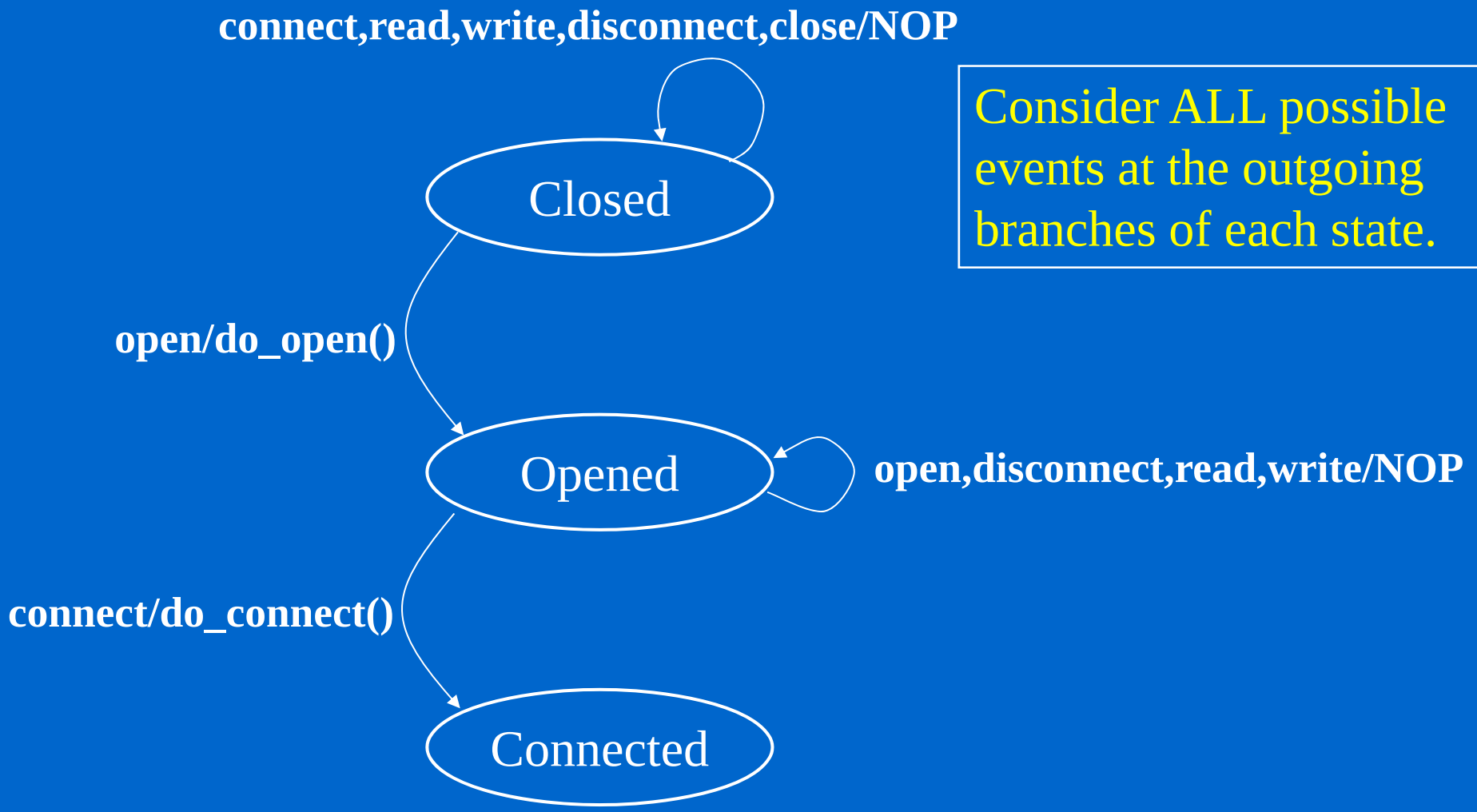

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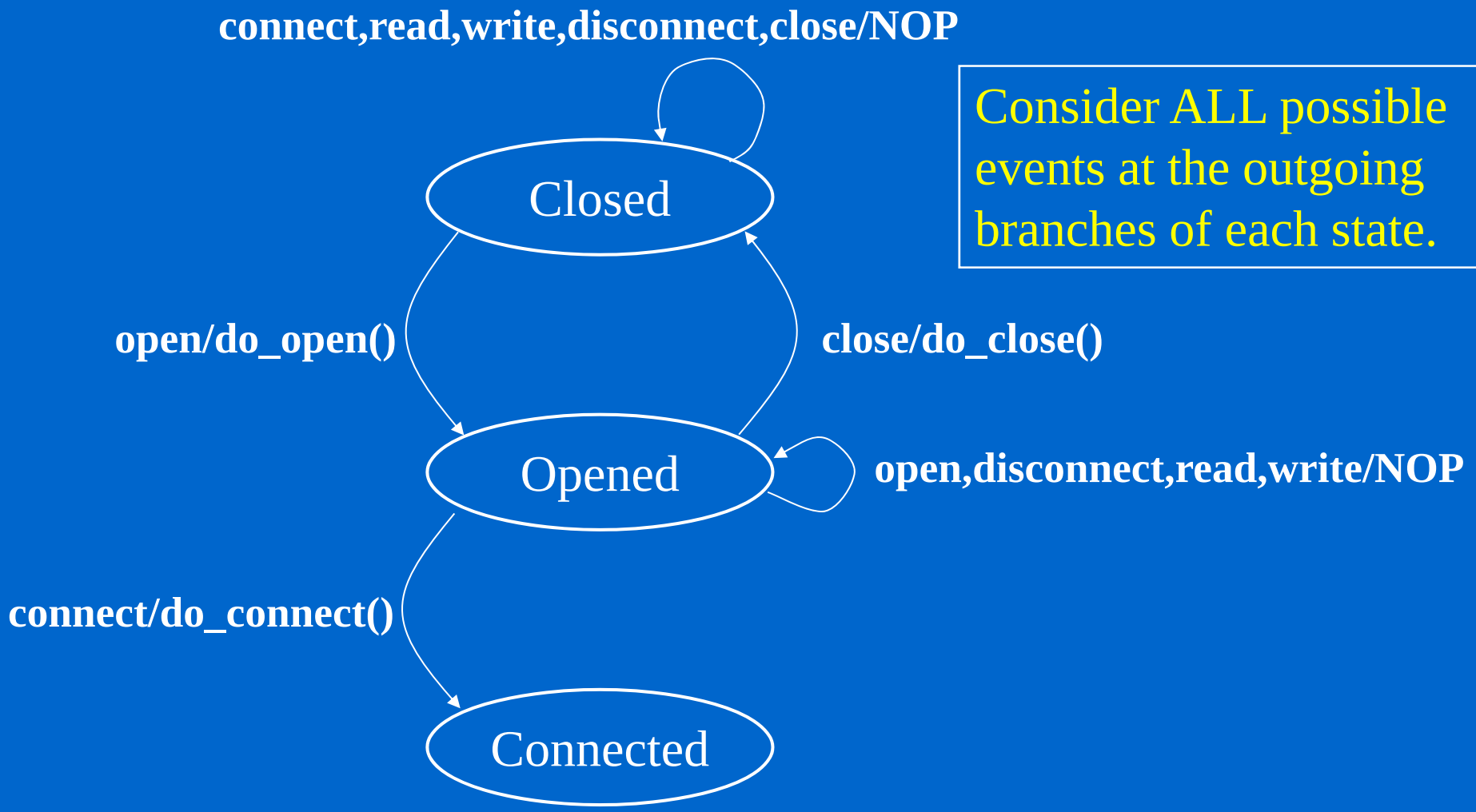

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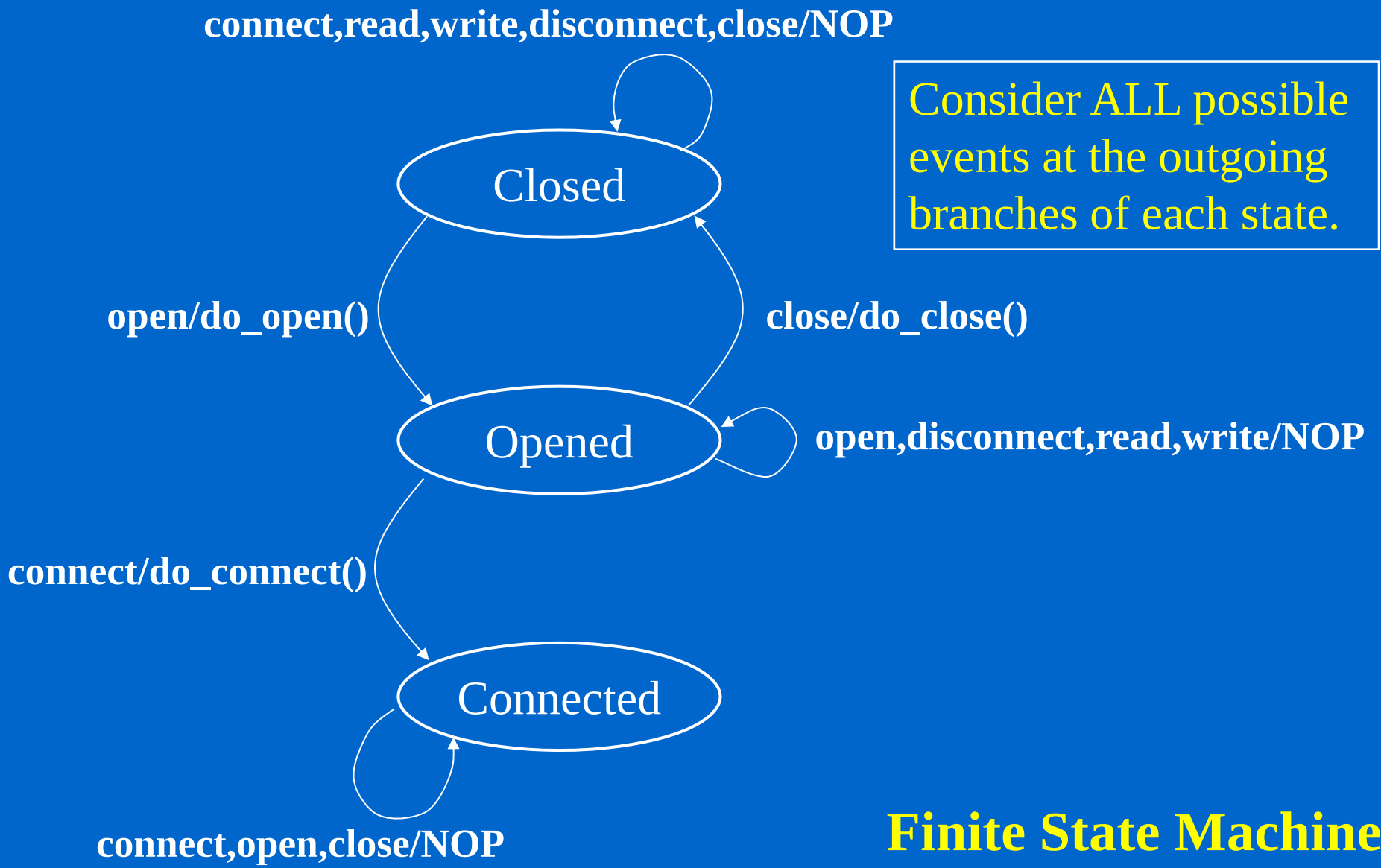

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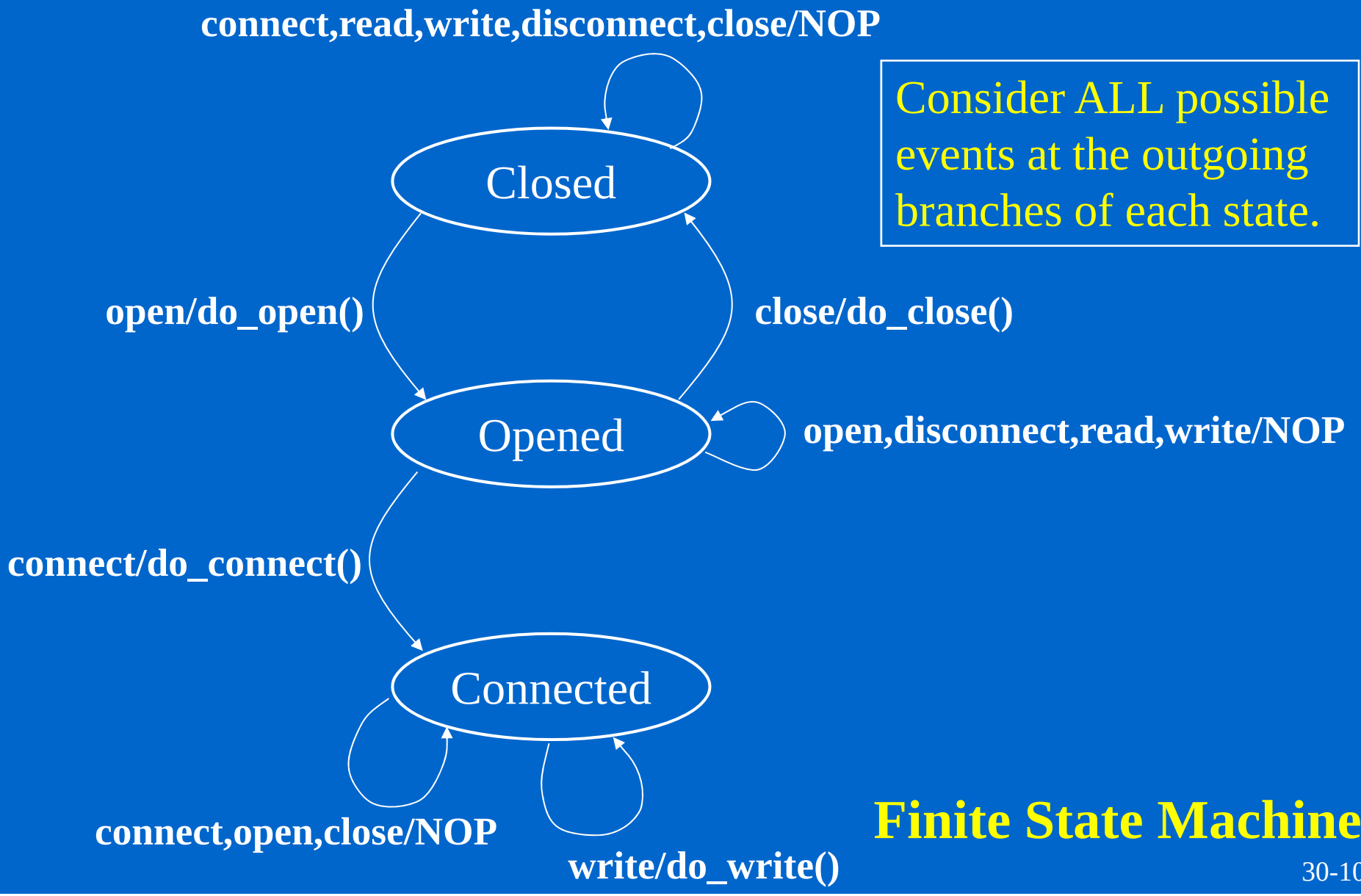

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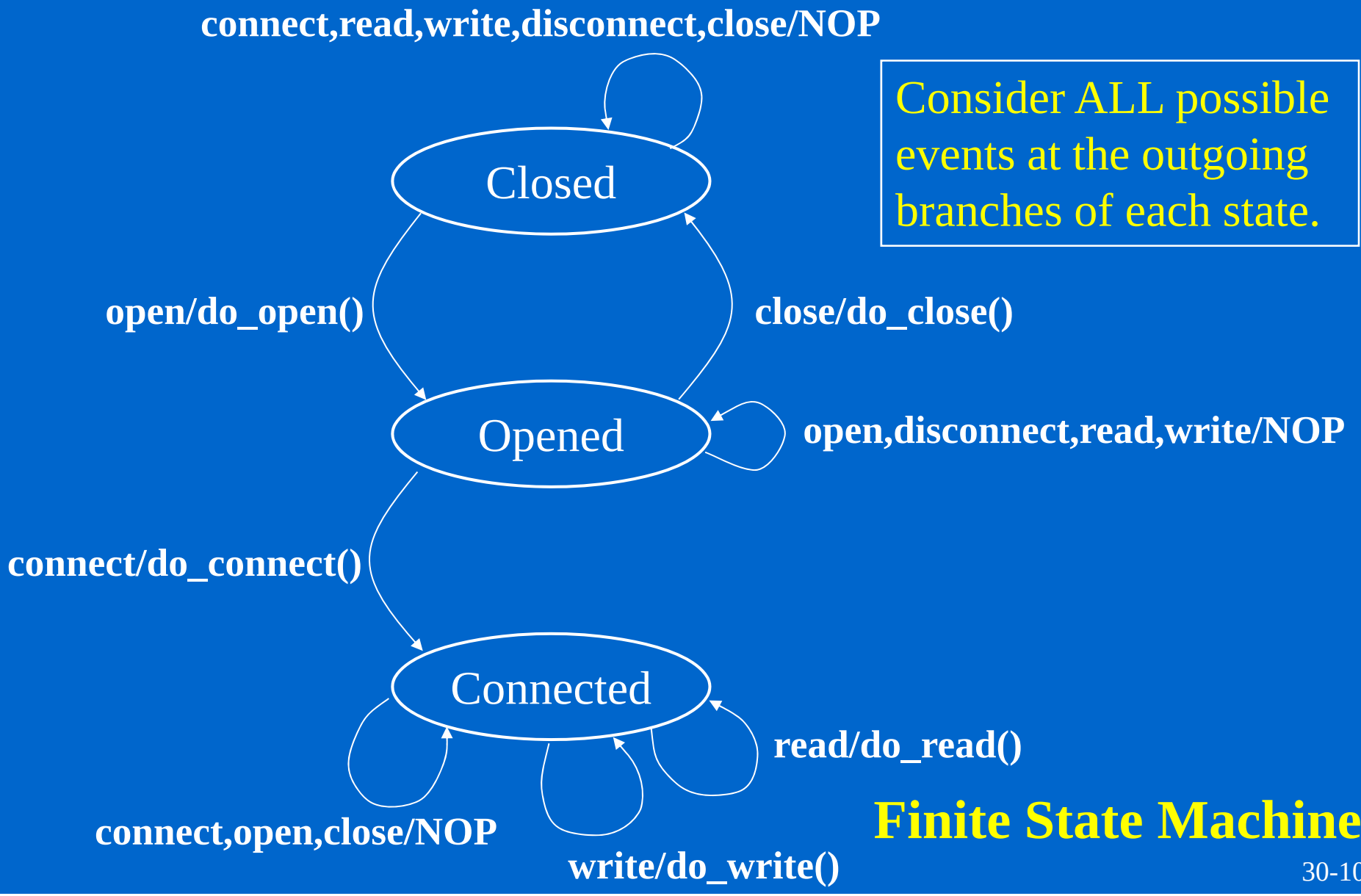

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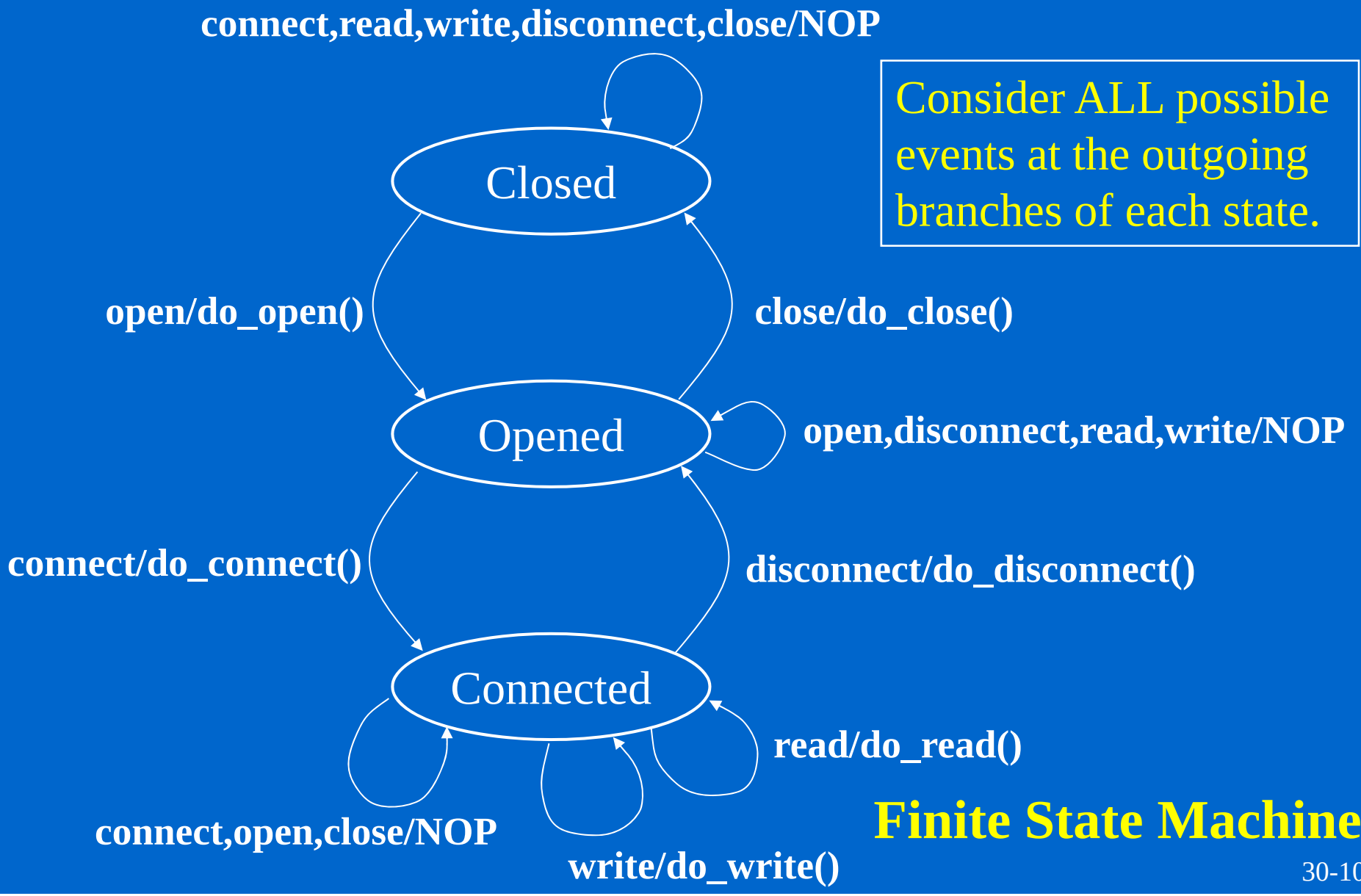

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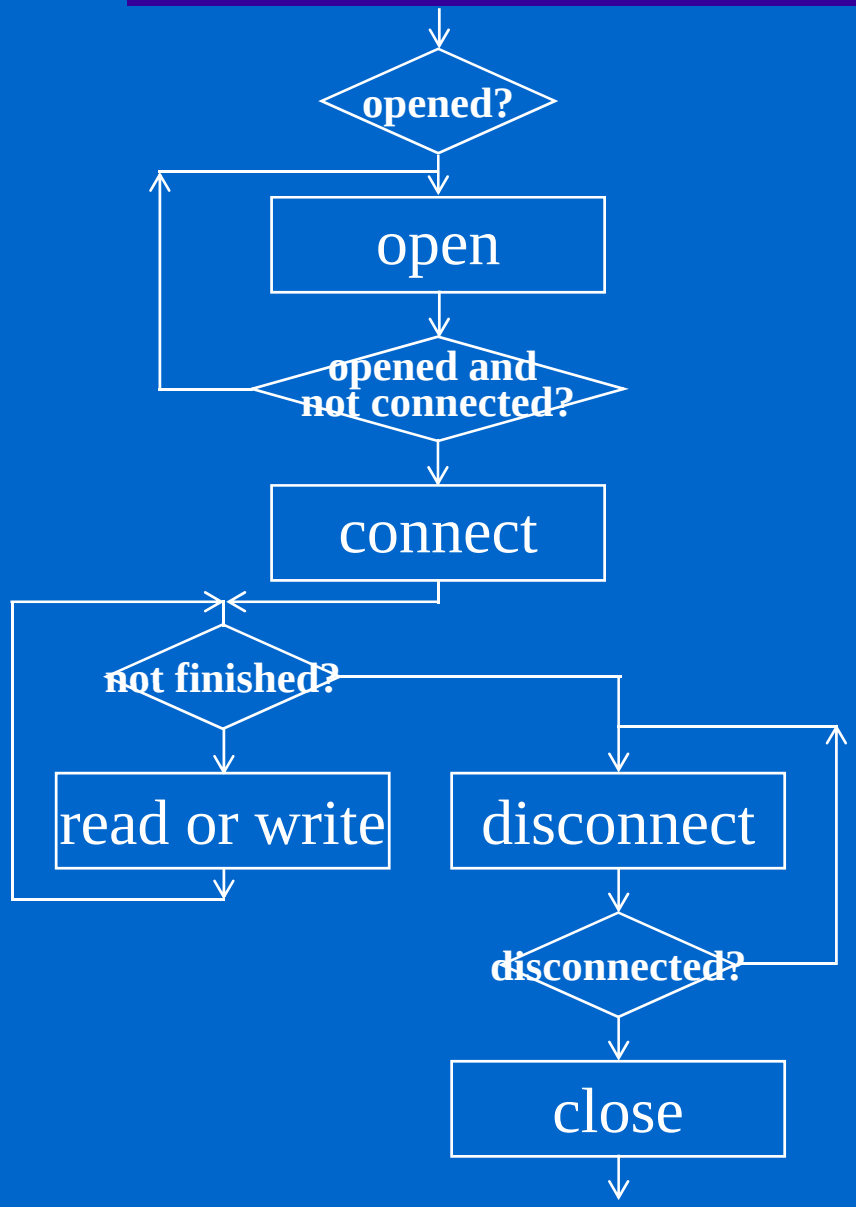

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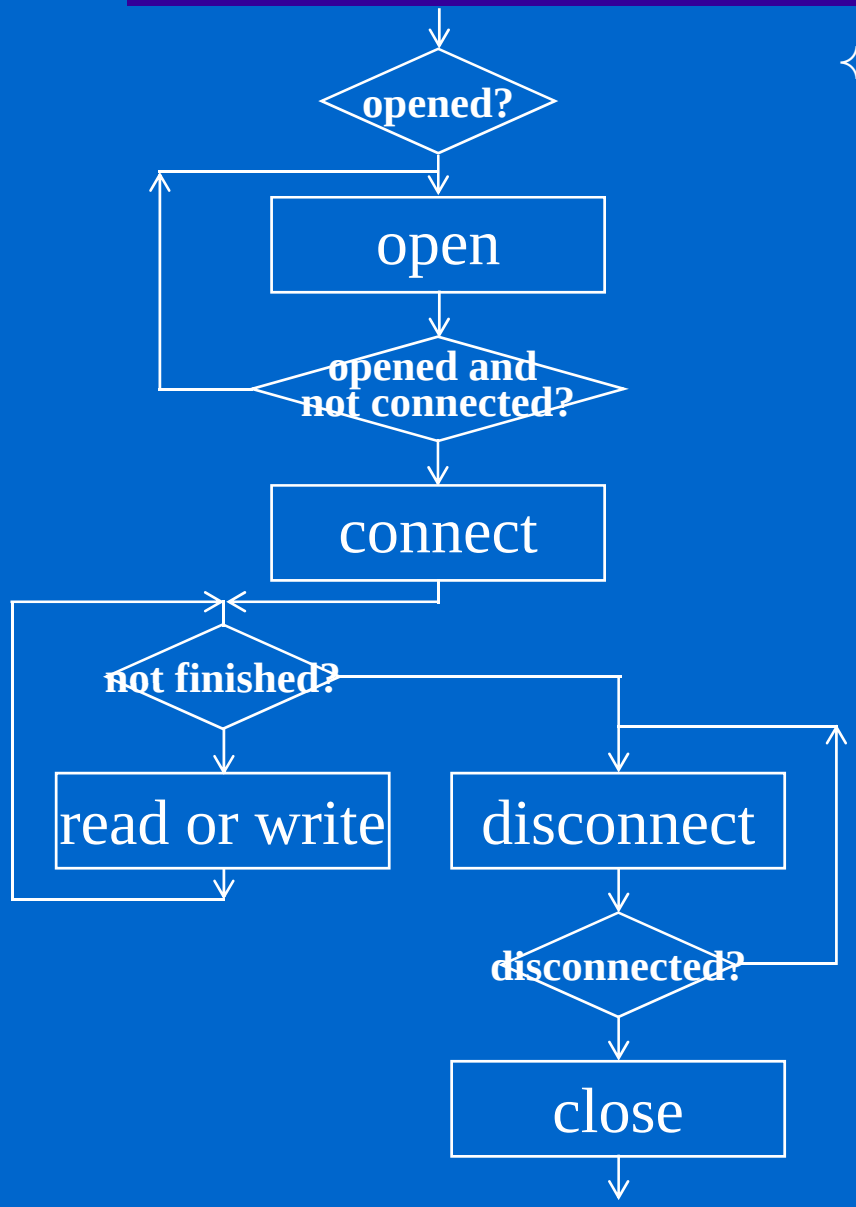
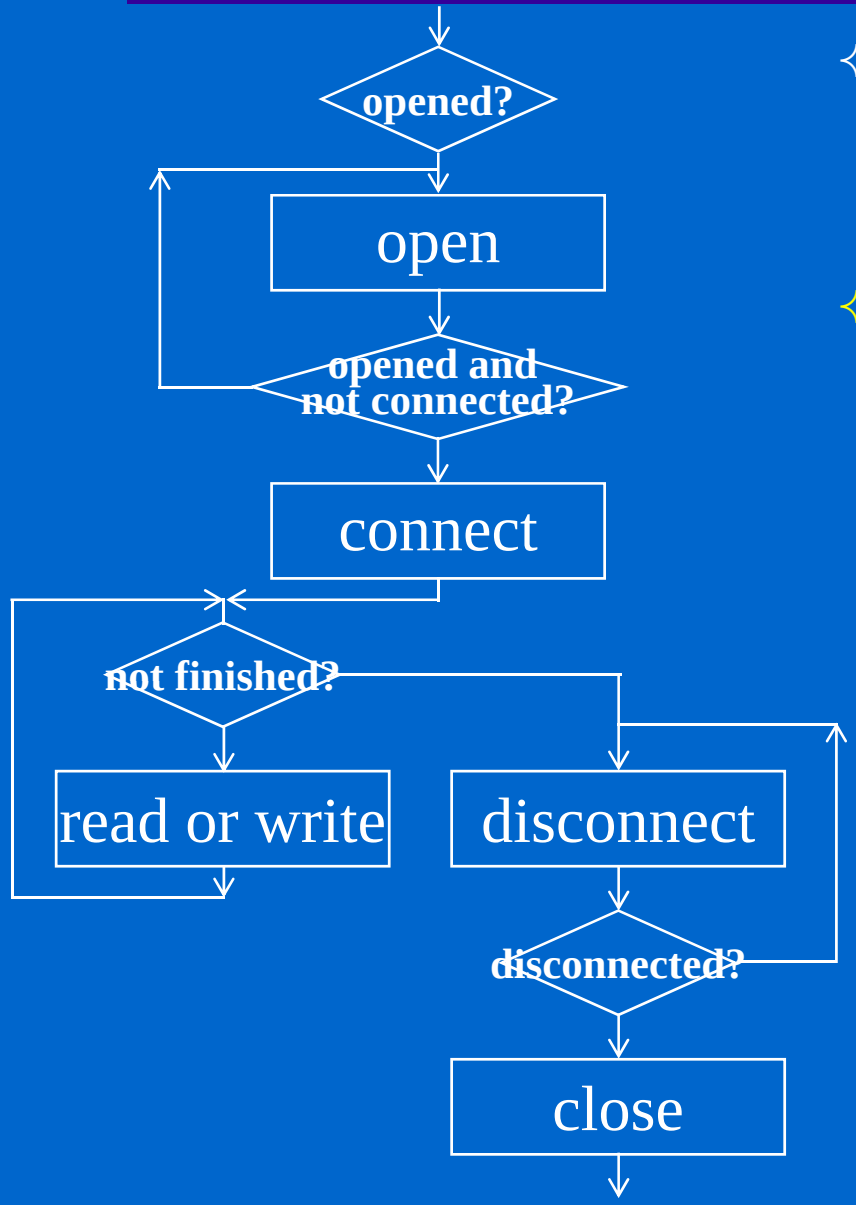


- This is the control flow for the TYPICAL / CORRECT usage of this NetCommStream object.

Control Flow Diagram of A Client



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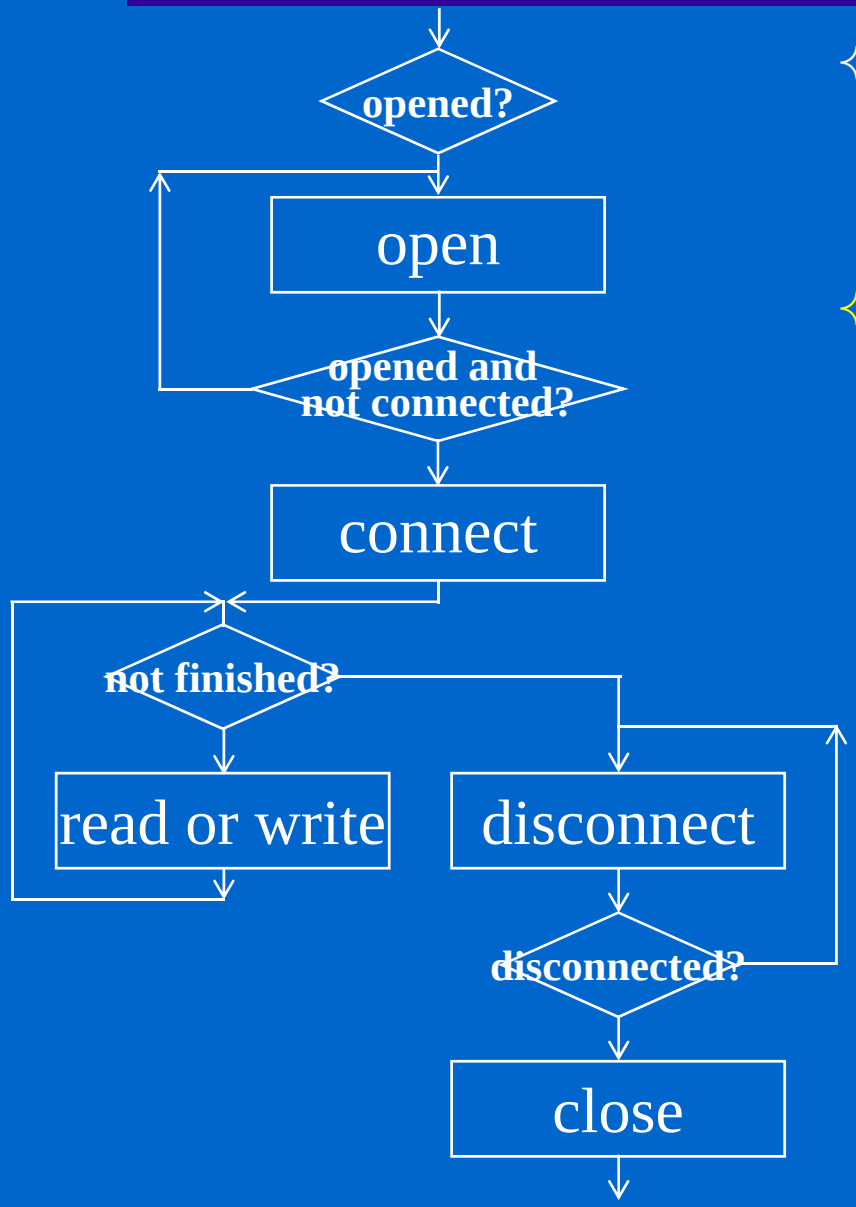
Control Flow Diagram of A Client



- This is the control flow for the TYPICAL / CORRECT usage of this NetCommStream object.
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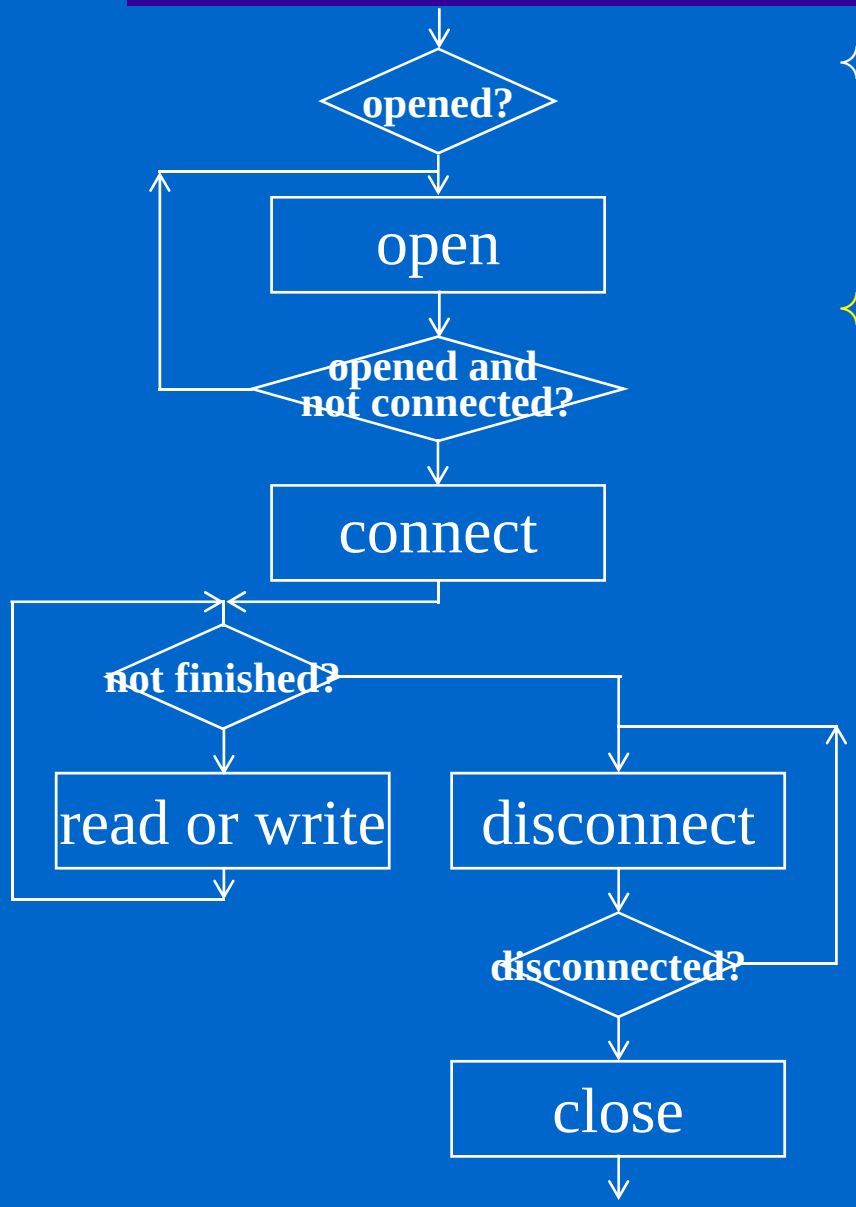
    Eg. Not opened but do the connect at the first step? Not connected but do the read/write at the second step?

Control Flow Diagram of A Client



- This is the control flow for the TYPICAL / CORRECT usage of this NetCommStream object.
- Problems:
  - What if the client does not follow this advised procedure?
    Eg. Not opened but do the connect at the first step? Not connected but do the read/write at the second step?
  - What if there are other possible usage patterns?
    e.g. Opened but find no peer to connect and then close immediately.
    Disconnected but find some other peer to connect.

Implementation of an FSM

- Use a single *enum* type of variable to represent the state of the system

  enum InternalStates {***Closed***, ***Opened***, ***Connected***};
  InternalStates **m_state**;

- In an OO system, objects communicate with each other through events. Take the event open and its handler open() as example:

  1. For each open message of each state in the diagram
  2. Implement the response in open()

```
void open() {
   if (m_state == Closed) {
      do_open();
      m_state = Opened;
   }
   else if (m_state == Opened) ;
   else if (m_state == Connected) ;
}
```

A systematic way of implementation for a state diagram

Implementation (cont'd)

```
void close() {
    if (m_state == Opened ) {
        do_close();
        m_state = Closed;
    }
}
```

Implementation (cont'd)

```
void close() {
    if (m_state == Opened ) {
        do_close();
        m_state = Closed;
    }
}

void connect() {
    if (m_state == Opened ) {
        do_connect();
        m_state = Connected;
    }
}
```

Implementation (cont'd)

```
void close() {
    if (m_state == Opened ) {
        do_close();
        m_state = Closed;
    }
}

void connect() {
    if (m_state == Opened ) {
        do_connect();
        m_state = Connected;
    }
}

void disconnect() {
    if (m_state == Connected ) {
        do_disconnect();
        m_state = Opened;
    }
}
```

Implementation (cont'd)

```
void close() {
    if (m_state == Opened ) {
        do_close();
        m_state = Closed;
    }
}

void connect() {
    if (m_state == Opened ) {
        do_connect();
        m_state = Connected;
    }
}

void disconnect() {
    if (m_state == Connected ) {
        do_disconnect();
        m_state = Opened;
    }
}
```

```
void read() {
    if (m_state == Connected )
        do_read();
}
```

Implementation (cont'd)

```
void close() {
    if (m_state == Opened ) {
        do_close();
        m_state = Closed;
    }
}

void connect() {
    if (m_state == Opened ) {
        do_connect();
        m_state = Connected;
    }
}

void disconnect() {
    if (m_state == Connected ) {
        do_disconnect();
        m_state = Opened;
    }
}
```

```
void read() {
    if (m_state == Connected )
        do_read();
}

void write() {
    if (m_state == Connected )
        do_write();
}
```

Modification over State Diagram

- If the system specification is modified such that it is allowed to close at the Connected state

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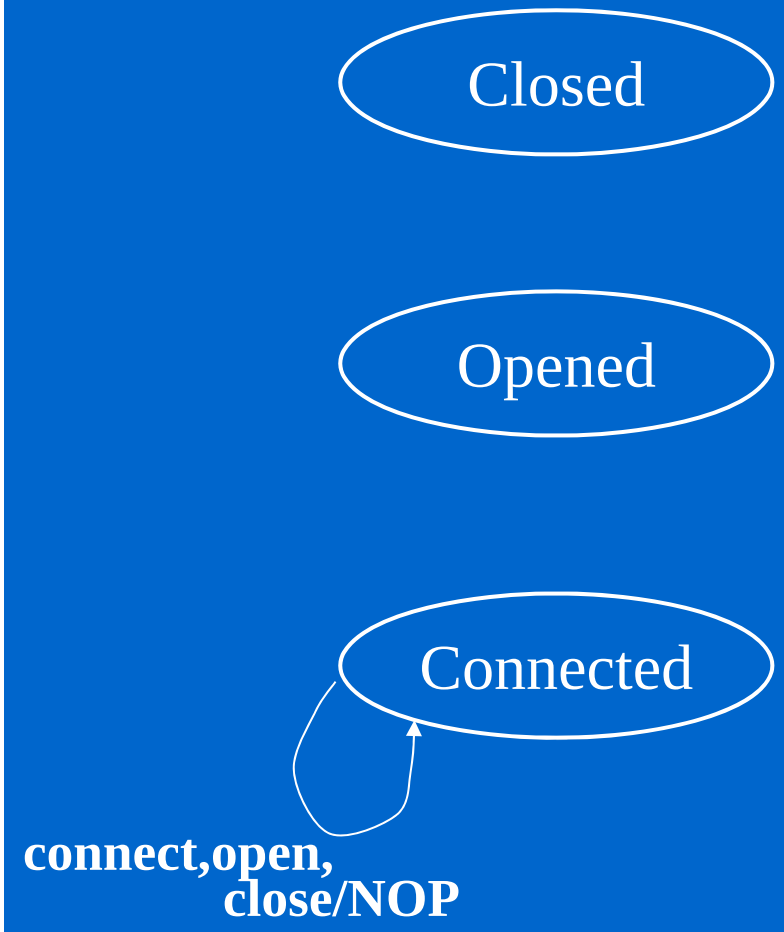

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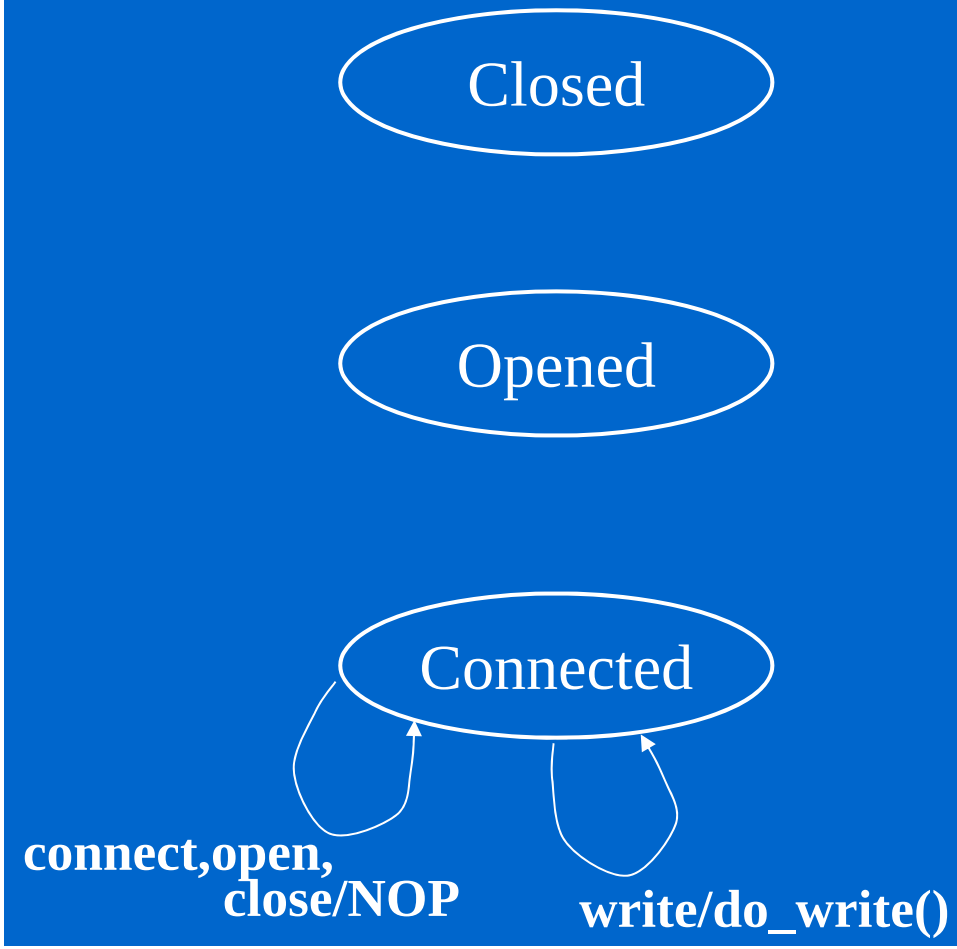

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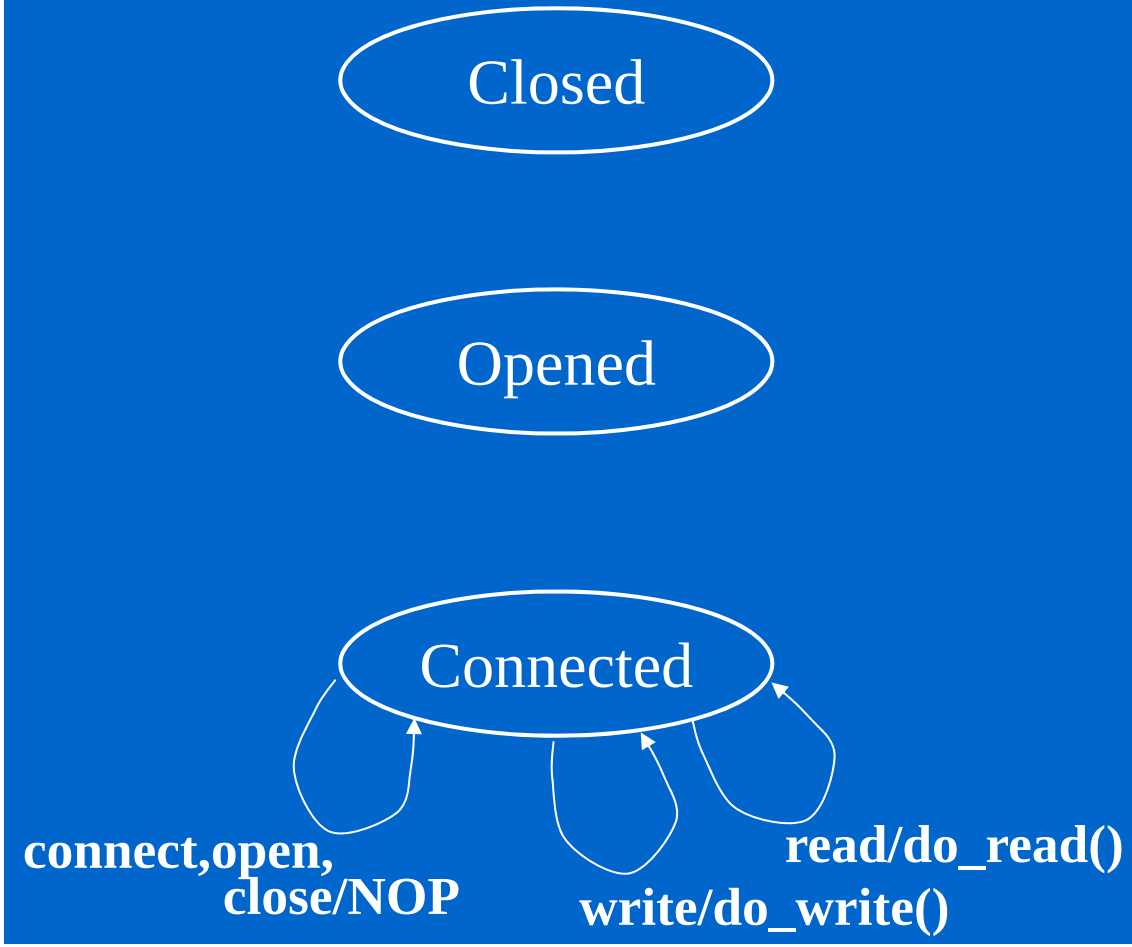

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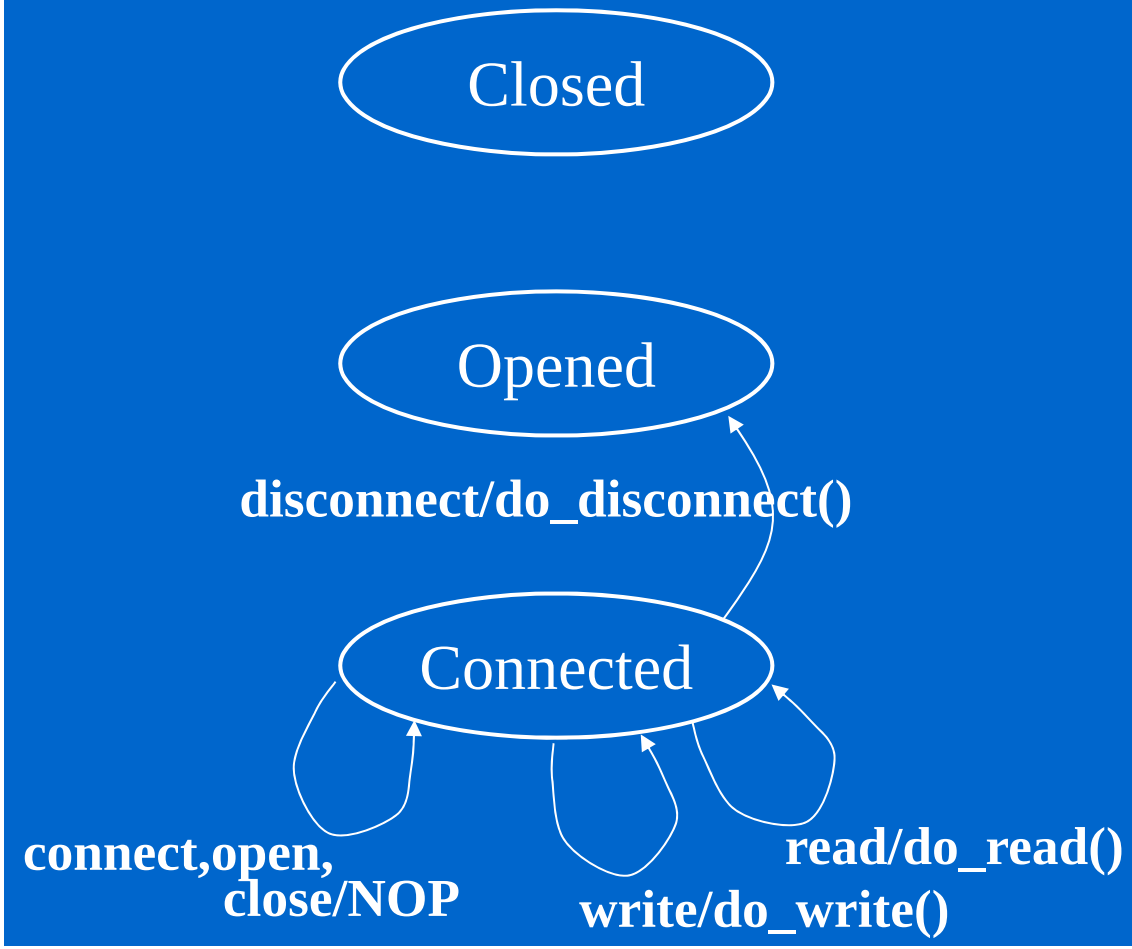

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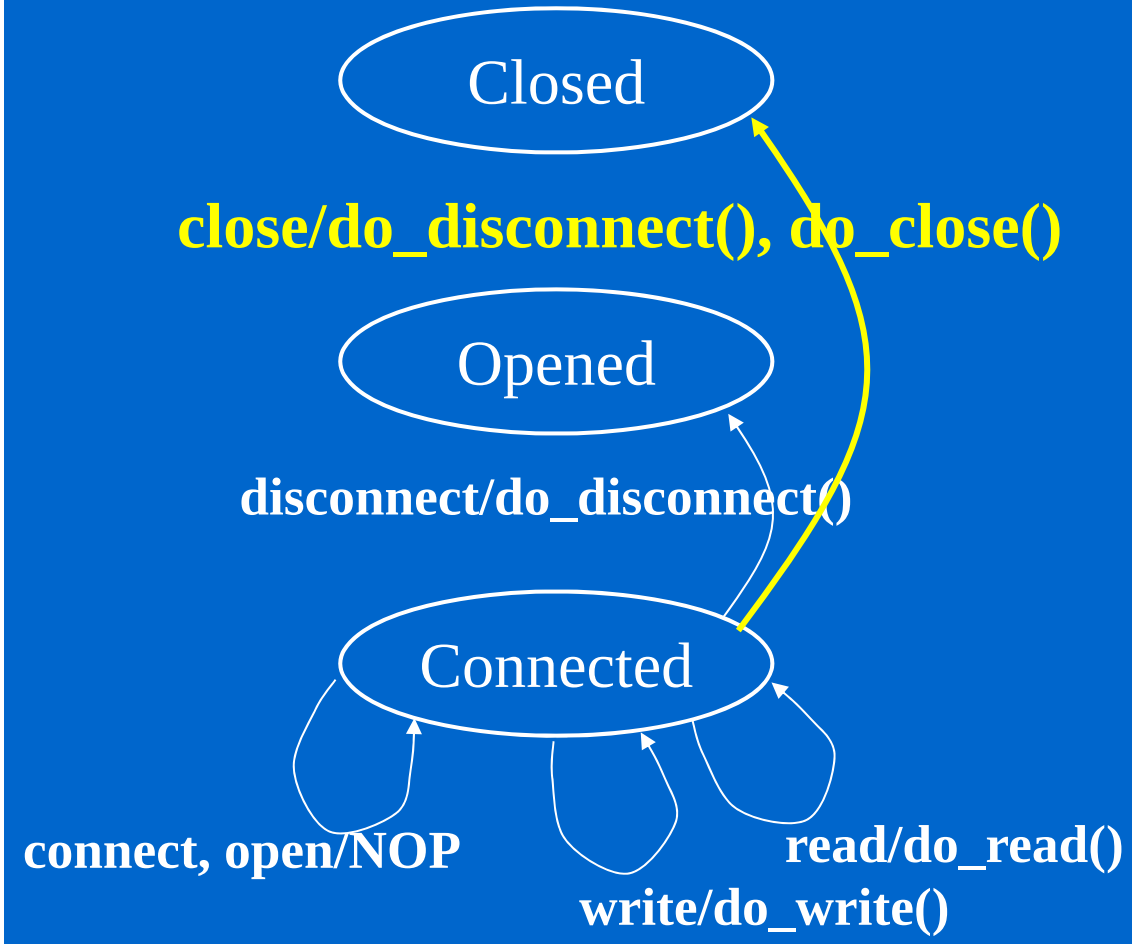

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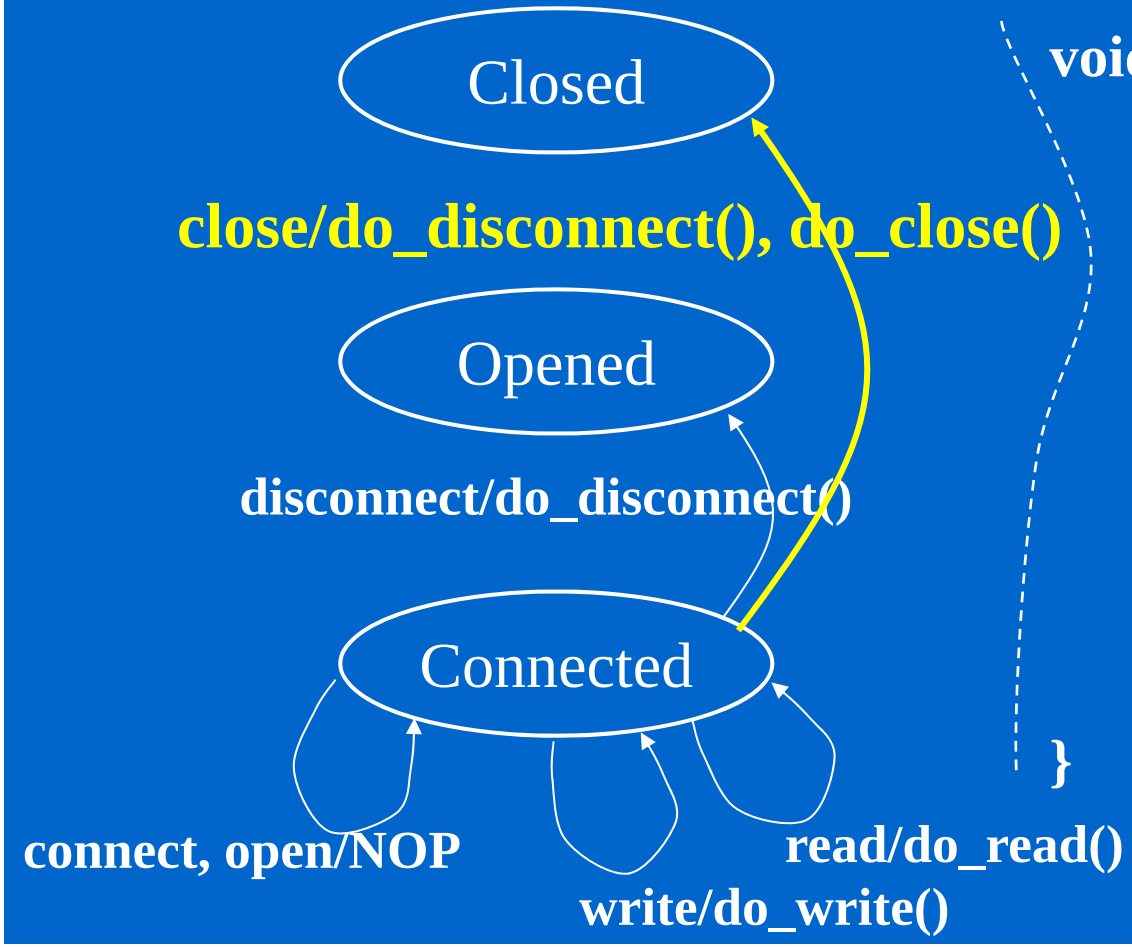

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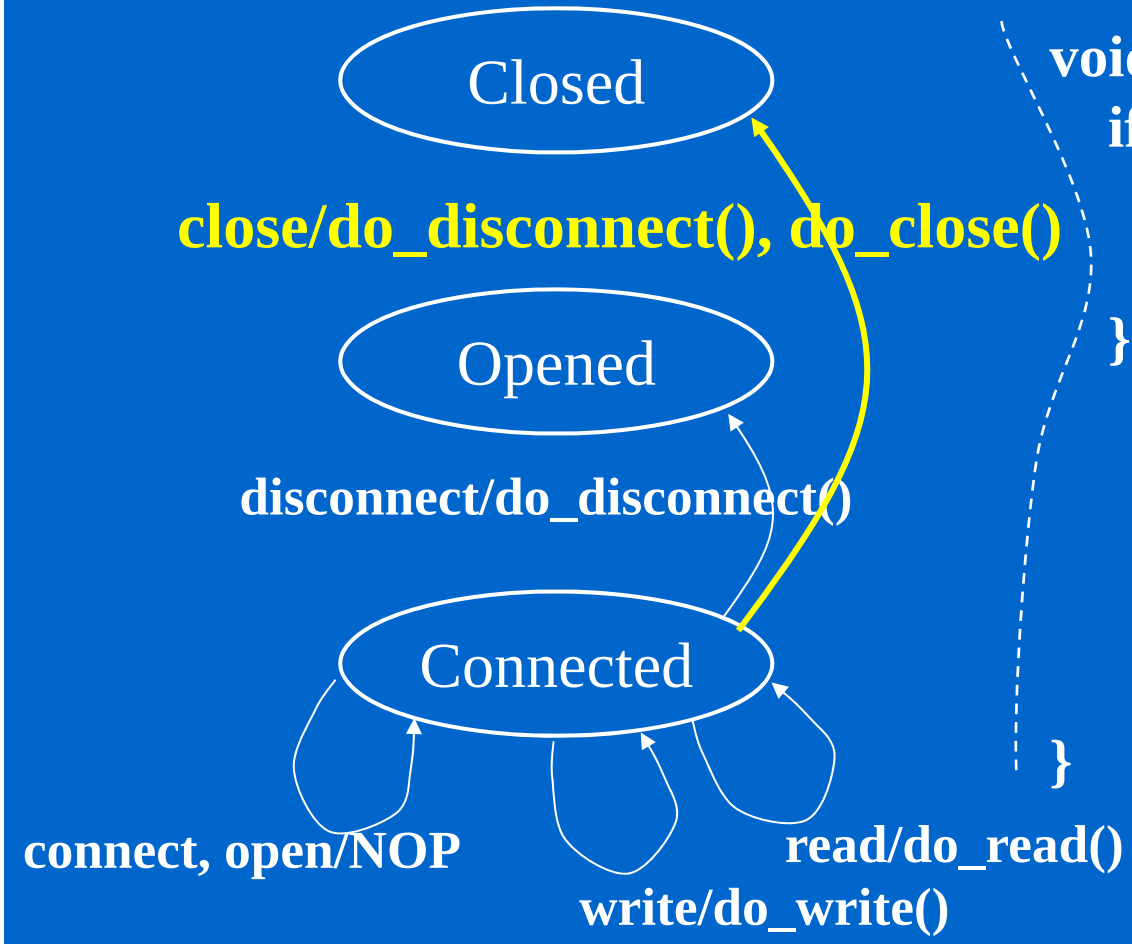


```
void close() {
    if (m_state == Opened) {
        do_close();
        m_state = Closed;
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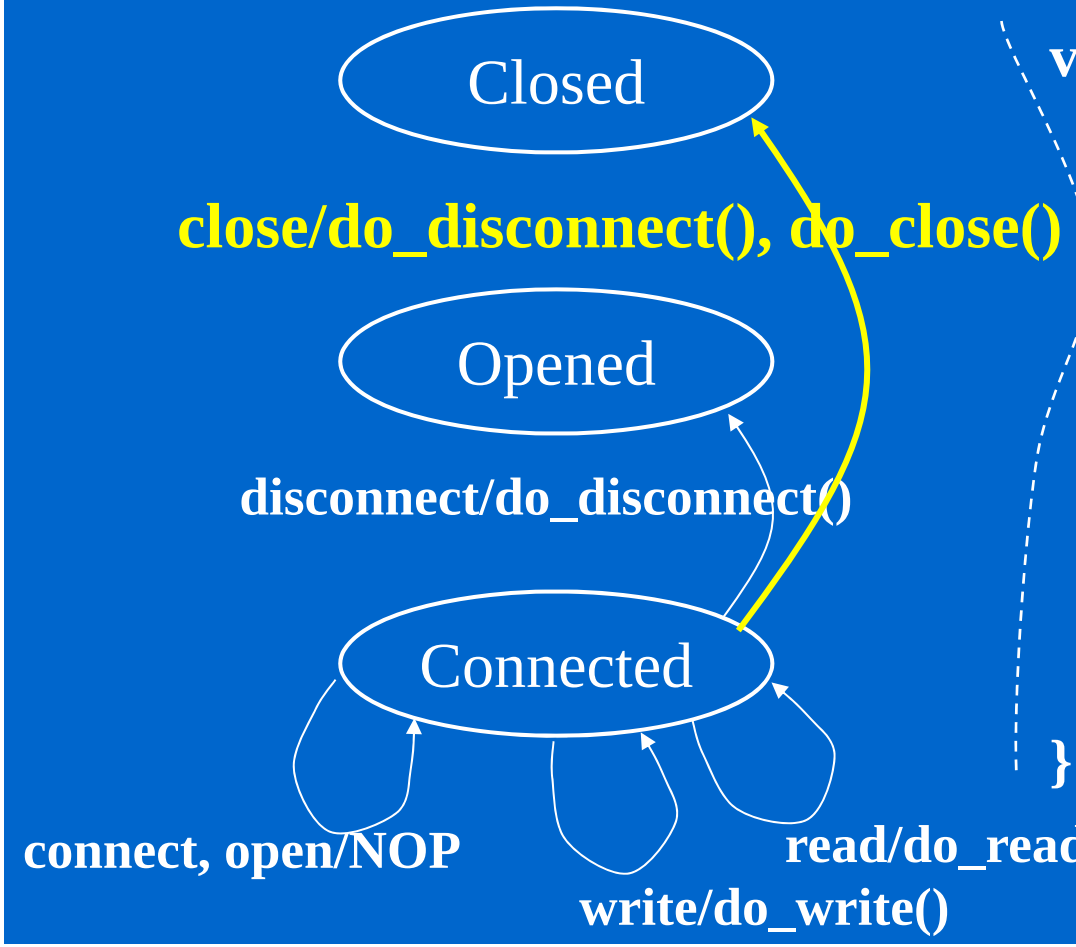


```
void close() {
    if (m_state == Opened) {
        do_close();
        m_state = Closed;
    }
    else if (m_state == Connected ) {
        do_disconnect();
        do_close();
        m_state = Closed;
    }
}
```

Second Implementation

- Use two ***enum*** types for the **state** of the system and the **event**

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  enum **State** {***Closed***, ***Opened***, ***Connected***};
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- Implement all actions as functions

  void do_open() { … }
  void do_connect() { … }
  void do_read() { … }
  void do_close() { … }
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- Use a static **state** variable inside the Transition function

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  void do_read() { … }
  void do_close() { … }
  void do_disconnect() { … }
  void do_write() { … }

- Use a static **state** variable inside the Transition function

  void Transition(Event **event**) {

  }

Second Implementation

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  enum **State** {***Closed***, ***Opened***, ***Connected***};
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```
void Transition(Event event) {
  static State state = Closed;
                                    }
```

Second Implementation

- Use two ***enum*** types for the **state** of the system and the **event**

```
enum State {Closed, Opened, Connected};
enum Event {open, connect, read, write, disconnect, close};
```

- Implement all actions as functions

```
void do_open() { … }          void do_close() { … }
void do_connect() { … }       void do_disconnect() { … }
void do_read() { … }          void do_write() { … }
```

- Use a static **state** variable inside the Transition function

```
void Transition(Event event) {
    static State state = Closed;
    switch (state) {
    }
}
```

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void Transition(Event event) {
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    case Closed:
    case Opened:
    case Connected:
    }
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```

- Use a static **state** variable inside the Transition function

```
void Transition(Event event) {
    static State state = Closed;
    switch (state) {
    case Closed:
        switch (event) {
        case open:
            do_open(); state = Opened;
        } break;
    case Opened:
                                    case Connected:
                                    }
}
```

Second Implementation

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```
enum State {Closed, Opened, Connected};
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void do_open() { … }          void do_close() { … }
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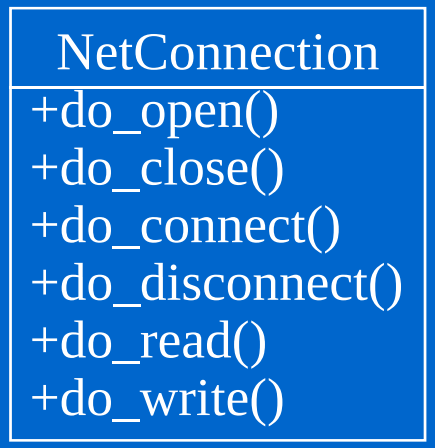
```
void Transition(Event event) {
    static State state = Closed;
    switch (state) {
    case Closed:
        switch (event) {
        case open:
            do_open(); state = Opened;
        } break;
    case Opened:
        switch (event) {
        case connect:
            …
        case close:
            …
        } break;
    case Connected:
        …
    }
}
```

OO Way – the State Pattern



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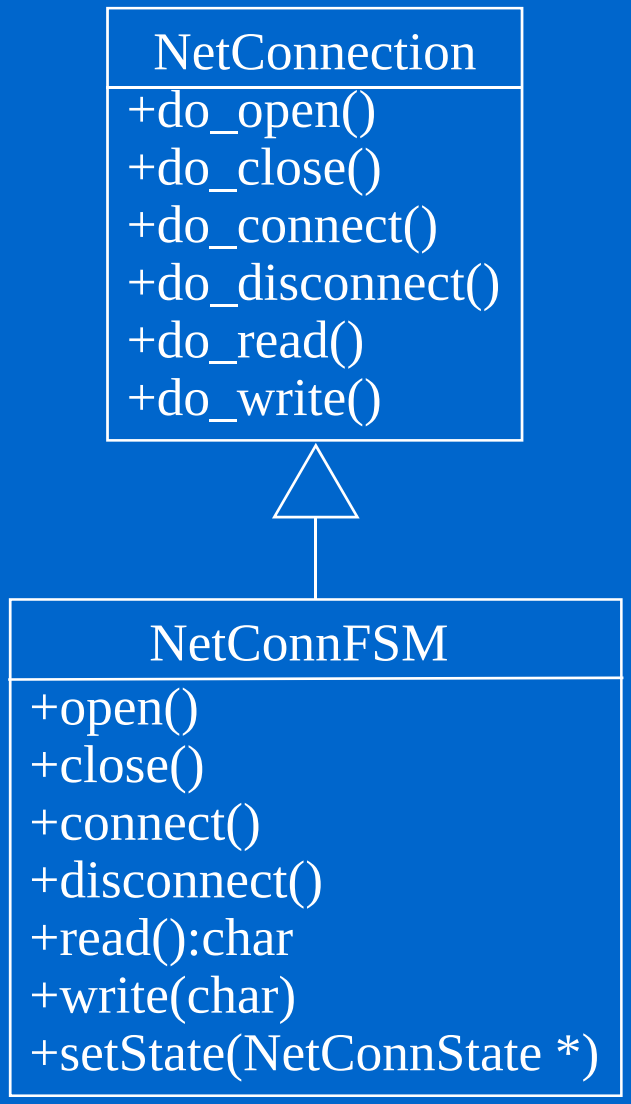

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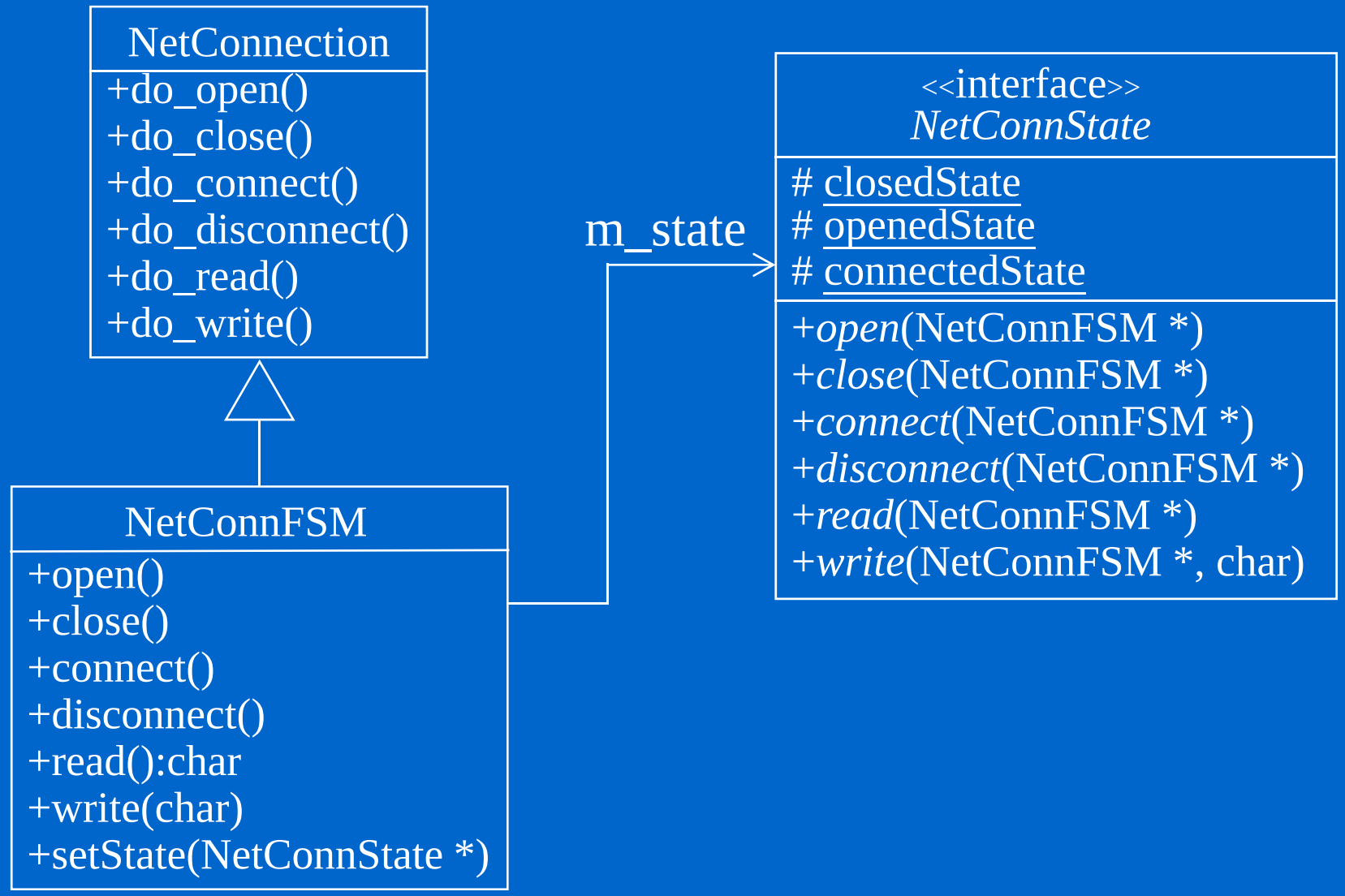
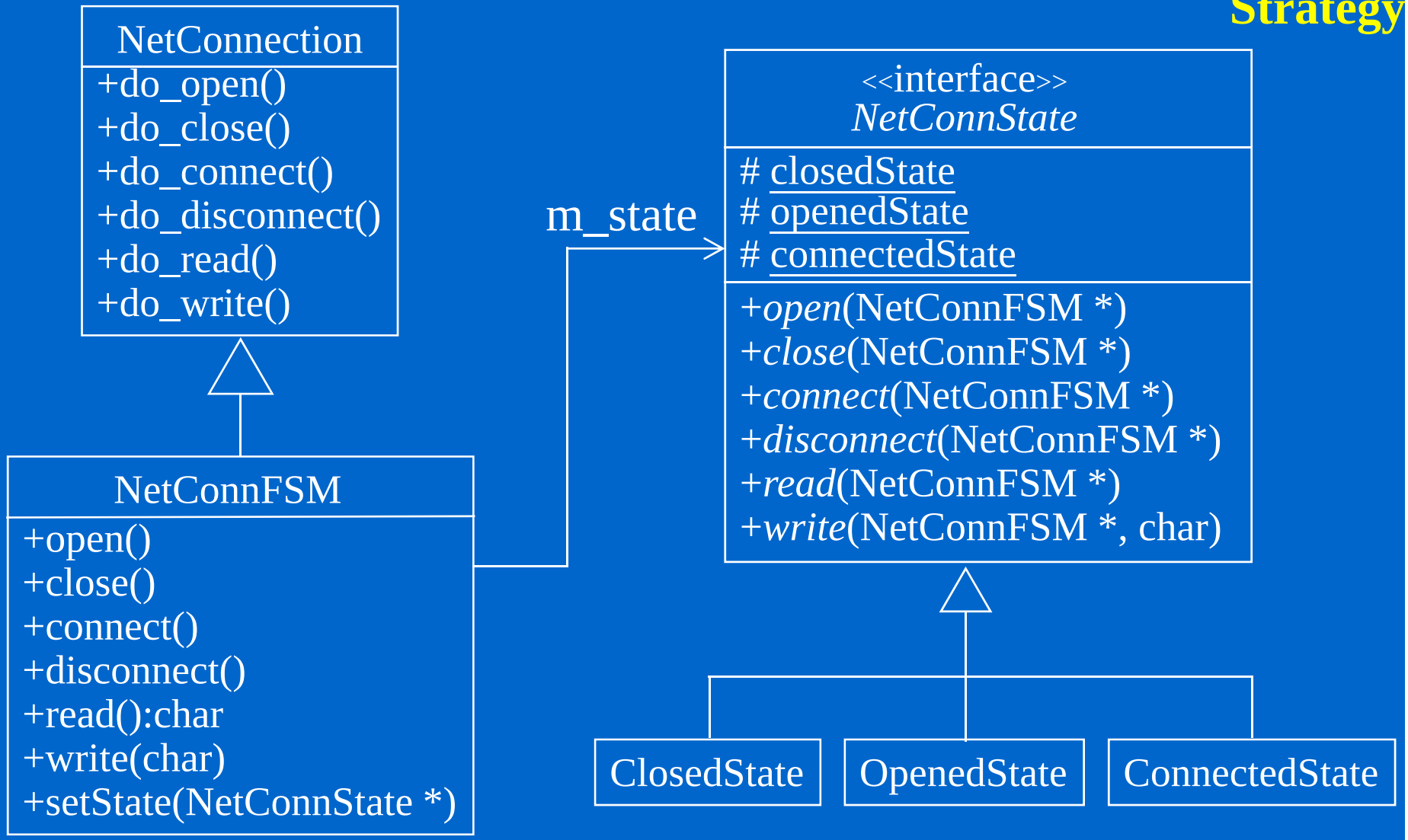


OO Way – the State Pattern

Strategy



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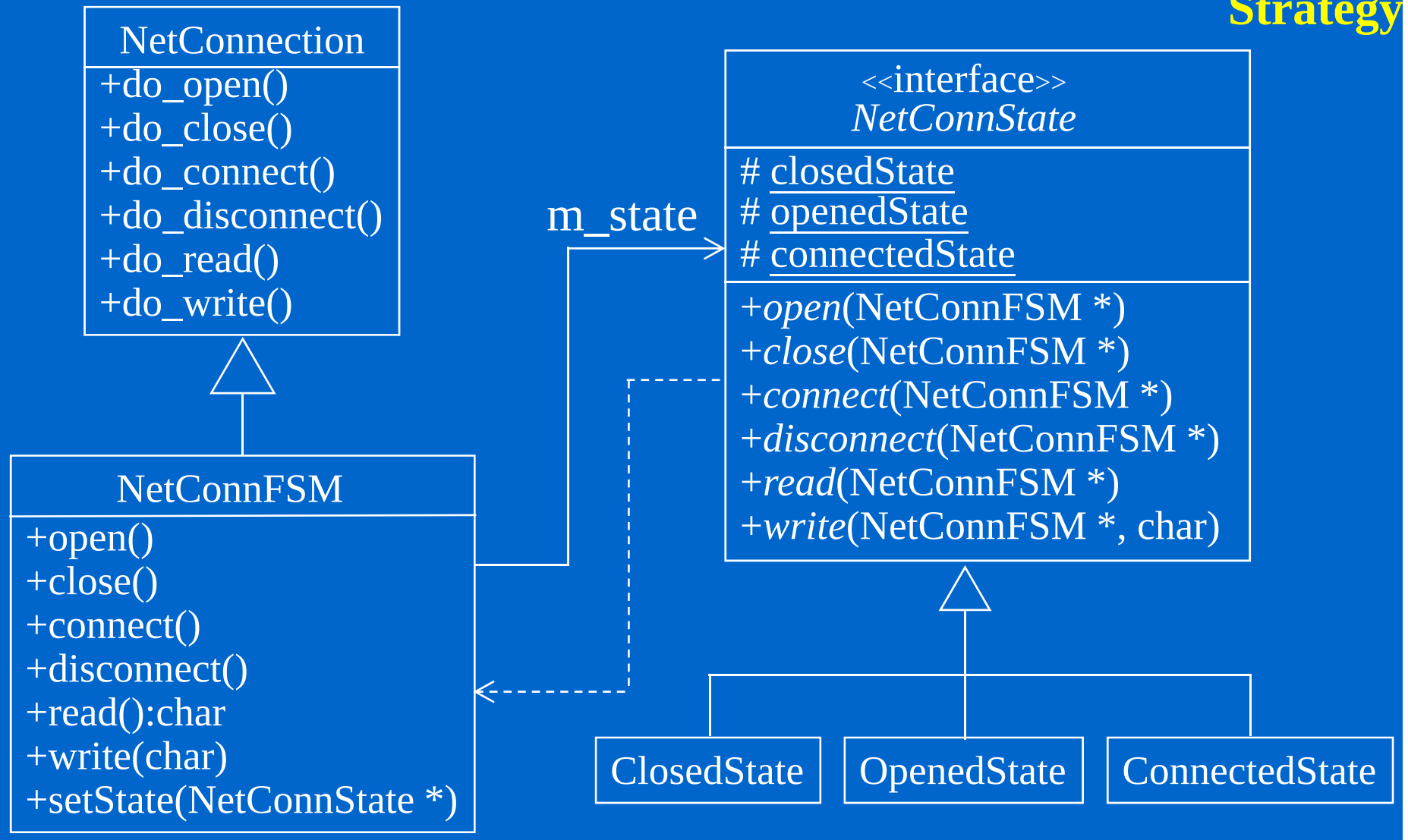

Implementation (1/4)

- Actual network operations

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```
class NetConnection {
public:
    void do_open() { … }          void do_close() { … }
    void do_connect() { … }       void do_disconnect() { … }
    char do_read() { … }          void do_write(char x) { … }
};
```

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```

- Interface for all states

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};
```

- Interface for all states

```
class NetConnState {
public:
    virtual void open(NetConnFSM *) = 0;  virtual void close(NetConnFSM *);
    virtual void connect(NetConnFSM *);   virtual void disconnect(NetConnFSM *);
    virtual char read(NetConnFSM *);      virtual void write(NetConnFSM *, char);
protected:
    static ClosedState closedState;
    static OpenedState openedState;
    static ConnectedState connectedState;
};
```

Implementation (1/4)

- Actual network operations

```
class NetConnection {
public:
    void do_open() { … }          void do_close() { … }
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- Interface for all states

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class NetConnState {
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    virtual void open(NetConnFSM *) = 0;  virtual void close(NetConnFSM *);
    virtual void connect(NetConnFSM *);   virtual void disconnect(NetConnFSM *);
    virtual char read(NetConnFSM *);      virtual void write(NetConnFSM *, char);
protected:
    static ClosedState closedState;
    static OpenedState openedState;
    static ConnectedState connectedState;
};
```

```
ClosedState NetConnState::closedState;
OpenedState NetConnState::openedState;
ConnectedState NetConnState::
                    connectedState;
```

Singleton

Implementation (2/4)

- the Finite State Machine

Implementation (2/4)

- the Finite State Machine

```
class NetConnFSM: public NetConnection {
public:
    NetConnFSM():m_state(&closedState) {}
    void setState(NetConnState *s) { m_state = s; }
    void open() { m_state->open(this); }
    void close() { m_state->close(this); }
    void connect() { m_state->connect(this); }
    void disconnect() { m_state->disconnect(this); }
    char read() { return m_state->read(this); }
    void write(char x) { m_state->write(this, x); }
private:
    NetConnState *m_state;
};
```

Implementation (2/4)

- the Finite State Machine

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class NetConnFSM: public NetConnection {
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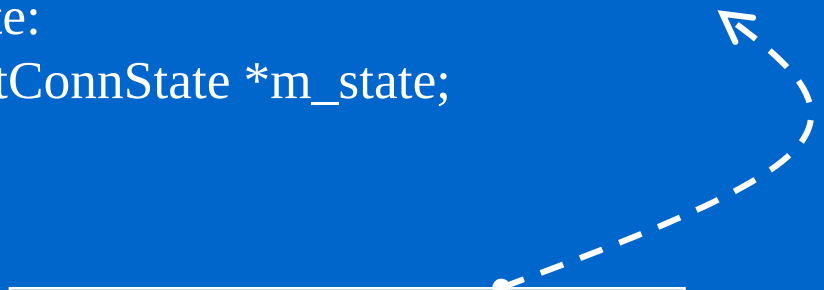

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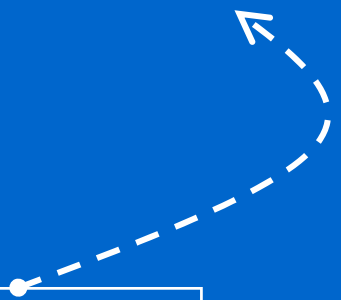

Strategy, delegation of events
Closed for modification

- Usage:

Implementation (2/4)

- the Finite State Machine

```
class NetConnFSM: public NetConnection {
public:
    NetConnFSM():m_state(&closedState) {}
    void setState(NetConnState *s) { m_state = s; }
    void open() { m_state->open(this); }
    void close() { m_state->close(this); }
    void connect() { m_state->connect(this); }
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    char read() { return m_state->read(this); }
    void write(char x) { m_state->write(this, x); }
private:
    NetConnState *m_state;
};
```

- Usage:

```
void main() {
    NetConnFSM conn_obj;
    conn_obj.open();
    conn_obj.connect();
    int x=conn_obj.read();
        …
    conn_obj.write(x);
        …
    conn_obj.disconnect();
    conn_obj.close();
}
```

Implementation (2/4)

- the Finite State Machine

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class NetConnFSM: public NetConnection {
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Strategy, delegation of events
Closed for modification

- Usage:

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void main() {
    NetConnFSM conn_obj;
    conn_obj.open();
    conn_obj.connect();
    int x=conn_obj.read();
      …
    conn_obj.write(x);
      …
    conn_obj.disconnect();
    conn_obj.close();
}
```

real event sequence

Implementation (3/4)

- Actual states

```
class ClosedState: public NetConnState {
public:
    void open(NetConnFSM *fsm) {
        fsm->do_open();
        fsm->setState(&openedState);
    }
    void connect(NetConnFSM *) {}
    char read(NetConnFSM *) { return 0; }
};
```

```
void close(NetConnFSM *) {}

void disconnect(NetConnFSM *) {}
void write(NetConnFSM *, char) {}
```

Implementation (3/4)

- Actual states

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class ClosedState: public NetConnState {
public:
    void open(NetConnFSM *fsm) {
        fsm->do_open();
        fsm->setState(&openedState);
    }
    void connect(NetConnFSM *) {}
    char read(NetConnFSM *) { return 0; }
};
```

```
void close(NetConnFSM *) {}

void disconnect(NetConnFSM *) {}
void write(NetConnFSM *, char) {}
```

```
class OpenedState: public NetConnState {
public:
    void open(NetConnFSM *) {}
    void close(NetConnFSM *fsm) {
        fsm->do_close();
        fsm->setState(&closedState);
    }
    char read(NetConnFSM *) { return 0; }
    void write(NetConnFSM *, char) {}
};
```

```
void connect(NetConnFSM *fsm) {
    fsm->do_connect();
    fsm->setState(&connectedState);
}
void disconnect(NetConnFSM *) {}
```

Implementation (4/4)

```
class ConnectedState: public NetConnState {
public:
    void open(NetConnFSM *) {}
    void close(NetConnFSM *) {}
    void connect(NetConnFSM *) {}
    void disconnect(NetConnFSM *fsm) {
        fsm->do_disconnect();
        fsm->setState(&openedState);
    }
    char read(NetConnFSM *fsm) {
        return fsm->do_read();
    }
    void write(NetConnFSM *fsm, char x) {
        fsm->do_write(x);
    }
};
```

Implementation (4/4)

```
class ConnectedState: public NetConnState {
public:
    void open(NetConnFSM *) {}
    void close(NetConnFSM *) {}
    void connect(NetConnFSM *) {}
    void disconnect(NetConnFSM *fsm) {
        fsm->do_disconnect();
        fsm->setState(&openedState);
    }
    char read(NetConnFSM *fsm) {
        return fsm->do_read();
    }
    void write(NetConnFSM *fsm, char x) {
        fsm->do_write(x);
    }
};
```

- Implemented through the “Strategy” and “Singleton” patterns

Implementation (4/4)

```
class ConnectedState: public NetConnState {
public:
    void open(NetConnFSM *) {}
    void close(NetConnFSM *) {}
    void connect(NetConnFSM *) {}
    void disconnect(NetConnFSM *fsm) {
        fsm->do_disconnect();
        fsm->setState(&openedState);
    }
    char read(NetConnFSM *fsm) {
        return fsm->do_read();
    }
    void write(NetConnFSM *fsm, char x) {
        fsm->do_write(x);
    }
};
```

- Implemented through the “Strategy” and “Singleton” patterns
- Object Mentor Finite State Machine Compiler for Java/C++ code
  http://www.objectmentor.com/resources/bin/smcJava.zip