SAPIENZA Università di Roma – MSc. in Engineering in Computer Science
Formal Methods - Final Test A – December 21, 2017
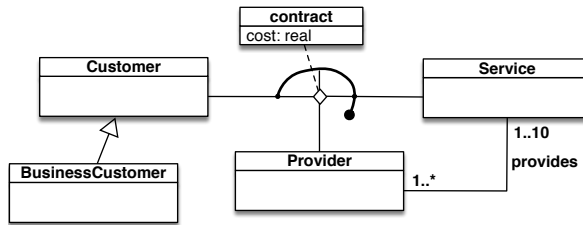*(Time to complete the test: 2 hours)*

Exercise 1. Express the following UML class diagram in FOL:

Exercise 2. Consider the above UML class diagram and the following (partial) instantiation:

1. Check whether the above instantiation, once completed, is correct, and explain why it is or it is not.

2. Express in FOL the following queries and evaluate them over the completed instantiation:

   (a) Check that, for every provider x and service y involved in a contract, provider x does provide service y.

   (b) Return those customers that have contracts only for services provided by $p1$.

   (c) Return those customers that have a contract for all services.

Exercise 3. Model check the Mu-Calculus formula $\nu X.\mu Y.((a \wedge [next]X) \vee (b \wedge \langle next \rangle Y))$ and the CTL formula $AF(EG(a \supset AXEX\neg a))$(showing its translation in Mu-Calculus) against the following transition system:
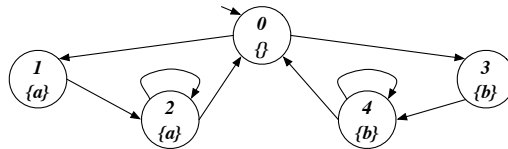
Exercise 4. Check whether the Hoare triple below is correct, by using $(x \geq 0 \wedge y \geq 0 \wedge x + y = 23)$ as invariant:

$$\{x = 23 \wedge y = 0\} \text{ while(x>0) do (x=x}-1\text{; y:= y+1) } \{y = 23\}$$

Exercise 5. Check whether the following FOL formula is valid, by using tableaux:

$$(\forall x.P(x) \wedge \forall x.Q(x)) \equiv \forall x.(P(x) \wedge Q(x))$$

Exercise 6 (optional). Model check the LTL formula $\Diamond\Box\neg a$ against the following transition system, by considering that the Büchi automaton for $\neg(\Diamond\Box\neg a)$ is the one below: